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African Development Bank
Angle des l'avenue du Ghana et des rues
Pierre de Coubertin et Hédi Nouria
BP 323 -1002 TUNIS Belvédère (Tunisia)
Tél: +216 71 333 511
Fax: +216 71 351 933
E-mail: afdb@afdb.org

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AFRICAN DEVELOPMENT BANK GROUP

Inflation Targeting, Exchange Rate Shocks and Output: Evidence from South Africa

Mthuli Ncube and Eliphas Ndou⁽¹⁾

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⁽¹⁾ Mthuli Ncube and Eliphas Ndou are respectively Chief Economist and Vice President of the African Development Bank, Tunis, Tunisia (M.Ncube@afdb.org) and Researcher at the South African Reserve Bank, Research Department, Pretoria, South Africa.
"This paper will also appear in the Reserve Bank of South Africa research papers"

Abstract

This paper derives the inflation equation to search for a possible transmission channel between the real interest rate, inflation rate, exchange rates, real output growth rate using a Bayesian VAR sign restriction approach. Our findings show that the real interest rate reacts negatively to inflation rate shocks and the Fisher effect holds in the long run. We show that strict inflation targeting approach is not compatible with significant real output growth. However a

flexible inflation-targeting framework which attaches a large weight to the role of real effective exchange rates results in a significant real output growth given the Central Bank desire to accumulate more foreign exchange reserves and high oil price inflation. Thus real effective exchange rate measuring competitiveness against trading partners matters more than domestic currency and nominal effective exchange rate depreciations.

JEL Classification: E31, E40, E52, E60

Keywords: Inflation shocks, real interest rate, sign restriction, output growth, inflation-targeting

1. Introduction

South African monetary policy authorities have in several occasions managed to bring the inflation rate within the target band of 3-6% after adopting inflation targeting framework in February 2000. Economic growth in these periods was not significant enough to reduce unemployment rate. In February 2010, the mandate of the South African Central bank was clarified with emphasis on taking a balanced approach, which considers economic growth when monetary policy authorities set interest rates. In the inflation targeting era, the Central Bank has left the exchange rate to be determined by the market forces making it more volatile. Given this context, we examine the differences in the responses of real interest rate to the exchange rate shocks and inflationary shocks, at the same time we examine how these shocks impact on output growth performance. Moreover we investigate assuming that the Central Bank has desire to increase reserves accumulation and unexpected high oil prices environment using Bayesian sign restriction approach.

Inflation targeting is either strict or flexible, depending on the specified loss function of the central bank. Under strict inflation targeting, the central bank is only concerned about keeping inflation close to an inflation target over the shorter horizon (Svensson 1997b). This requires very vigorous activist policies, which involve dramatic interest rate and exchange rate changes. This happens with considerable variability of exchange rates, interest rates, output, employment and domestic component of inflation. To some extent the activism probably stabilize inflation around the inflation target. Flexible inflation targeting occurs when the central bank gives some weight to the stability of interest rates, exchange rates, output and employment to bring inflation to the desired long run target over longer horizon. It requires less policy activism which gradually returns the inflation back to target over a longer horizon.¹ Immediately after adopting inflation targeting approach applying a stricter approach clearly demonstrates the commitment to the inflation target, builds credibility more quickly, and is more appropriate at the initial phase of disinflation. However Svensson (1997b) argues that, after the bank has demonstrated commitment and established credibility to a reasonable degree, there may be more scope for flexibility without endangering credibility.

Most policy rate reaction functions for Central Banks in an open economy framework have output gap, inflation gap and exchange rate gap as explanatory variables. Following similar specification in literature, Granville and Mallick (2010) using monetary policy rule for an open economy tested empirically the reaction of the interest rate to exchange rate changes and inflation rate shocks. Estimation incorporated assumptions that the central bank has a desire to

¹ Flexible inflation targeting successfully limited not only the variability of inflation but also the variability of the output gap and the real exchange rate (Svensson 1997b).

accumulate more reserves even under a negative supply shock in form of higher oil prices. They imposed sign restrictions to identify exchange rate shocks and inflation shocks to examine impulse responses functions. They found, using an error correction form and a sign restriction approach that Russian monetary authorities focused more on targeting the exchange rate rather than inflation as an instrument for monetary policy.

Firstly, this paper fills the gap in the literature on emerging markets such as South Africa, by using a Bayesian sign restriction identification system to search the type of monetary policy the Central bank should adopt to support significant economic growth under flexible inflation targeting. Secondly, the paper shows that strict inflation targeting approach has a different growth path compared to the path under flexible inflation targeting framework, in which significant economic growth could be facilitated through a larger role attached to a particular exchange rate measure. Thirdly, we also identify the particular measure of exchange rate that is compatible with significant economic growth. Lastly, we derive the price formation equation and use the variables in the equation to show that exchange rate can be used to stimulate significant economic growth.

Recently, there has been great interest in models using large datasets based on factor analysis² founded on static factors in Bernanke et al (2005) and recently the dynamic factors in Forni and Gambetti (2010) and large Bayesian models by Banbura (2010). Factor analysis uses more information, however Forni and Gambetti (2010) exposition suggested that static factors may not have any economic interpretation and there are often difficulties on the restrictions to be satisfied by these factors according to theory. However, the above mentioned large datasets methodologies are not appropriate, based on merits of this study. According to Fry and Pagan (2007) sign restrictions have provided a useful technique for quantitative analysis, especially when variables are simultaneously determined, making it harder to justify any parametric restrictions to resolve the identification problem. However, Scholl and Uhlig (2008) rejected to embrace Fry and Pagan (2007) argument related to median impulse response in sign restrictions as an issue arising generally with all identification procedures. Even the latter admits identifications issues affect all forms of VARs not only those using sign restrictions.

We adopted the sign restriction approach of Granville and Mallick (2010) for this analysis. The Bayesian sign restriction methodology has advantages over ordinary Vector Autoregression (VAR). From a methodological perspective, Fratzscher et al (2010) argues that sign restriction gives results independent of chosen decomposition of variance–covariance matrix. This implies that different ordering does not change the result. Furthermore, this method involves a simultaneous estimation of both reduced-form VAR and the impulse vector. That is, the draws from the VAR parameters from the unrestricted posterior that do not satisfy the sign restriction,

² Factor models being parsimonious can model a large amount of information whereas in small VARS the number of variables cannot be enlarged because of both estimation and identification problems. Bernanke B, Boivin J, Elias P (2005) suggested that the natural solution to the degrees of freedom problem in VAR analyses is to augment standard VARs with estimated factors. Forni and Gambetti (2010) criticised BBE (2004) identification suggesting this static factors approach through considering factors which are linear combinations of slow-moving variables at the same time excluding fast-moving variables results in an efficiency loss.

receive a zero prior weight. Granville and Mallick (2010) argue that the sign restriction method is robust to non-stationarity of series including structural breaks. The advantage is that sign restriction identification allows shocks to be identified using mild restrictions on multiple time series. Rafiq and Mallick (2008) suggest restrictions imposed should happen irrespective of how these inflation, exchange rate variables are measured and their data idiosyncrasies, suggesting that definitions and measures of same class of variables used are of secondary importance.³ Furthermore, the sign restriction methodology does not put any quantitative restrictions on the impulse responses. A pure sign restriction approach makes explicit use of restrictions that researchers use implicitly and are therefore agnostic (Rafiq and Mallick 2008).⁴

The sign restrictions adopted from Granville and Mallick (2010), suggests that the oil price does not decrease as an exogenous positive shock, and the change in foreign exchange reserves excluding gold does not decrease in response to oil inflation. Inflation does not decline in response to its own shocks. The paper uses three exchange rates where the positive sign on the nominal Rand per US dollar implies depreciation of the local currency and the negative sign on both real and nominal effective exchange rates imply depreciations. The sign restrictions imposed suggests that the Rand per US Dollar exchange rate will not decline whereas the nominal and real effective exchange rate should not rise in response to their own shocks. Moreover, these exchange rates depreciation shocks occur due to own innovations, changes in foreign exchange reserves and with oil price inflation.

Our findings show that the real interest rate reacts negatively to inflation surprises and is not significantly different from zero in longer horizons suggesting that the Fisher effect hold in the long run. The paper showed that strict inflation targeting approach is not compatible with significant real output growth path. However, we found that under a flexible inflation-targeting framework, a significant real output growth could be facilitated through a larger role attached to the real effective exchange rate. The study, concludes that it is a measure of competitiveness relative to trading partners rather than smoothing the nominal exchange rate volatility levels which results in significant positive real output growth in the environment of accumulating reserves and uncertain high oil prices.

We structure the paper such that Section 2 reviews the literature evidence showing that other variables including the inflation rate matter for the Central Banks. In section 3, we derive the inflation equation, which shows the relationship amongst variables. Section 4 presents the data, methodology and describes the sign restriction approach. Sections 5 gives the results from pure sign restriction approach and summarize the findings from the penalty function. Section 6 gives the conclusion. The paper has additional graphs in the Appendices.

³ For example the different measures of inflation rate e.g. core inflation and headline inflation. Money measures M3 or M1 or M2

⁴ As shown in Uhlig (2005) the sign restriction can avoid puzzles by design, for example, price puzzle was avoided by construction.

2. Literature review

This section highlights evidence from inflation targeting regimes showing that variables other than inflation matter for policy makers, especially in the commodity exporting countries. Inflation targeting is divided into two broad groups, namely strict inflation and flexible inflation targeting. Strict inflation targeting suggests that the only concern of the central bank is to stabilize the inflation. It requires vigorous and more active policy changes, involving dramatic changes in interest and exchange rates. Flexible inflation targeting is when the central bank gives some weight to the stability of interest rates, exchange rates, output and employment (Svensson 1997b). The policy is conducted in such a manner that the conditional inflation forecast approaches the inflation target more slowly. The inflation forecast equals the inflation target at a longer horizon. Evidence showed that flexible inflation targeting successfully limited the variability of inflation, the variability of the output gap and the real exchange rate. In contrast, Aghion et al. (2009) showed that exchange rate volatility reduces productivity in developing countries, attributing it to financial channels. The findings showed the adverse effects of exchange rate volatility were larger for the less financially developed countries and are significant for practically all the emerging markets and developing countries.

Recent studies have reviewed whether central banks practice flexible inflation targeting. Cecchetti and Ehrmann (2000) compared central bank behaviours in 23 industrialised and developing economies including 9 that target inflation explicitly. They found that inflation targeters exhibited increasing aversion to inflation variability and decreasing aversion to output variability. Moreover, they show that inflation targeting countries were able to reduce inflation volatility at the expense of an increase in output variability. Aghion et al (2009) tested whether emerging markets follow pure inflation targeting rules or try to stabilize real exchange rates. Their findings indicated that inflation targeting markets practiced a mixed inflation targeting strategy. Inflation targeting central banks responded to both inflation and real exchange rates in setting interest rates. In addition, they find the strongest response to real exchange rate in countries following inflation targeting policies which are relatively intensive in exporting basic commodities.

A few studies estimated explicitly the Taylor rule equations for individual countries. Aizenman et al (2008) suggest that emerging markets which adopted inflation targeting were not following pure inflation targeting strategies. They found evidence showing that external variables played a very important role in the Central bank's policy reaction functions. Central banks respond to real exchange rate. In addition, inflation targeters with high concentration in commodity exports change interest rate in a proactive manner in response to real exchange rate than non-commodity intensive group. Corbo et al (2001) found mixed evidence from seventeen OECD countries estimated individually. Their results showed that inflation targeters exhibited the largest inflation coefficients compared to the output gap coefficients. Lubik and Schorfheide (2007) estimated Taylor type rules in which authorities reacted to output, inflation and exchange rates. The

findings reveal mixed responses indicating the Australian and New Zealand central banks changing interest rates in response to exchange rate movements. In contrast the Canadian did not respond to exchange rates.

De Mello and Moccero (2010) estimated interest rate policy rules for Brazil, Chile, Colombia and Mexico under the inflation targeting and floating exchange rates in 1999. The interest rate policy rule was formed in the context of the new Keynesian structural model with inflation, output and interest rate. Their findings suggest a stronger and persistent response to expected inflation in Brazil and Chile in the post 1999 inflation targeting period. In Colombia and Mexico monetary policy has become less counter-cyclical. Minella et al (2003) estimated a reaction function for the central bank of Brazil, and showed that the coefficient on output gap is not statistically significant in most of the specifications. Pavasuthipaisit (2010) develops a DSGE model that also concludes that inflation targeting regimes should respond to the exchange rate shocks under certain conditions that the paper outlines. Findings from their tests showed that the policy rule adopted by inflation targeting commodity-intensive developing countries differed from that of the inflation targeting non-commodity exporter. These finding give support to the greater sensitivity of commodity inflation targeting countries to exchange rate changes.

We derive the inflation equation and policy reaction rule in context of an open economy in the next section. We do not estimate both the policy reaction functions and inflation equations in a univariate setting. Rather we pursue a multivariate approach by estimating the entire structural model using a Bayesian sign restriction approach with variables from both equations.

3. The inflation equation framework

Before we search for a possible relationship between the real interest rate, inflation rate, exchange rate, foreign exchange reserves excluding gold growth and output growth (proxied by growth in manufacturing production) and oil prices, we derive the central bank price formation equation. The price formation equation is formed in the context of open economy suggesting that the exchange rate play an important role in decisions affecting demand and supply disturbances. Thus, we use the variables in the inflation equation and impose restrictions on them, assuming the inflation equation is followed by the central bank. The central bank has attached less weight to the role of exchange rate under the strict inflation-targeting framework which is expected to change under flexible inflation targeting framework.

3.1. Deriving the inflation equation

We adopt the approach of Granville and Mallick (2010) to derive the inflation equation and reaction function of monetary policy which includes the changes in flow of money (ΔMS_t) decomposed into international reserves (ΔIR_t) and domestic assets (ΔDA_t)

$$[1] \quad \Delta MS_t = \Delta IR_t + \Delta DA_t$$

Chamberlin (2006) showed that changes in international reserves can be expressed in terms of the trade balance. However we adjust the equation to take care of the imperfect capital mobility.

$$[2] \quad \Delta IR_t = (X_t - M_t) + K_t(r_t^d - r_t^f - \Delta e_t/e_t)$$

The trade balance is given by exports (X_t) minus imports (M_t) and capital flows (K_t) is determined by the difference between domestic interest rate (r_t^d) and foreign interest rate (r_t^f).⁵ A trade balance surplus suggests that the Central Bank is adding to reserves accumulation. ($\Delta e_t/e_t$) refers to the expected change in nominal bilateral exchange rate. An expectation of rand appreciation against the US dollar would lead to capital inflows. A positive interest differential which stimulates capital inflows should appreciate domestic currency leading to increased reserve accumulations. However the net effect of currency appreciation on reserves accumulation is unclear due to asymmetry effects. Currency appreciation lowers exports and it becomes cheaper to purchase foreign currency *ceteris paribus*. The flow of money demand (MD_t) for an open economy function depends on the level of real output (y_t), exchange rate (e_t) and real interest rate (r_t). The real interest rate is given by the difference between the nominal interest rate (i_t) and expected inflation (π_t^e) i.e $r_t = i_t - \pi_t^e$. The fisher effect suggests in the long run, real interest rates should not change because both the nominal interest rate and inflation rate would have changed by same percentage. We argue that since real interest rate is a linear combination of two non-stationary variables, it can be stationary in line with other first differenced variables hence this justifies it being left in levels.

$$[3] \quad \Delta MD_t = \alpha \Delta y_t - \gamma r_t - \eta \Delta e_t + v_t \quad \text{and} \quad \alpha, \gamma, \eta > 0$$

These variables have been log-differenced and expressed in percentages and the real interest rate left in level. Equation [3] shows that transaction demand for nominal balances increases as the expected inflation levels increases. The expected rate of depreciation in the money demand function captures the portfolio choice that asset holders face. The exchange rate changes may increase or reduce the demand for money due to substitution effect or the wealth effect (Hye et al 2009). According to Sriram (2001) the expected depreciation will have a negative effect on money demand. Thus, an increase in expected depreciation translates into higher expected returns from holding foreign money hence agents will substitute domestic currency for foreign

⁵ Balance of payments surplus = increase in official exchange reserves = current account surplus+ net capital inflow. Exports depends on exchange rate and foreign income whereas imports depends upon exchange rate and domestic income. Substituting the bilateral nominal exchange rate as defined in Blanchard (2006) $e_t = \left((1 + r_t^d) / (1 + r_t^f) \right) e_t^e$ suggest a direct negative relationship between high domestic interest, expected appreciation and lower foreign interest rate hence trade balance will deteriorate.

currency.⁶ The effect of interest rate on demand for currency would be negative with an increase in interest rate and positive for interest bearing demand and time deposits (Kalra 1998). Conversely, higher real rates of return on alternative assets reduce the incentive to hold money hence the negative relationship between money and return on alternative assets (Sriram 2001). Money demand is expected to be positively related to the level of activity. Assuming equilibrium in the money market holds continuously suggests that ($\Delta MD_t = \Delta MS_t$). Hence we can write the capital flow reaction equation as

$$[4] \quad \Delta DA_t = \alpha \Delta y_t - \gamma r_t - \eta \Delta e_t - \Delta IR_t + \nu_t$$

The inverse relationship between changes in international reserves and domestic assets implies that under flexible rate exchange policy, currency changes are likely to influence the conduct of monetary policy while under fixed exchange rates the bank should sterilize capital inflows to hold money constant. In equation [4] domestic residents may also hold foreign currency for transactions or precautionary purposes in the presence of domestic inflation meaning that domestic currency depreciation may lead to declines in real money balances encouraging currency substitution (Granville and Mallick 2010). Choudhry (1998) found that the rate of change in exchange rate should be included in demand equation for M2 to obtain a stationary long-run relationship. Bahmani-oskooee (1991) included the effective exchange rate measure in the money demand equation.

The aggregate inflation (π_t) supply equation can be formulated on the basis of an open economy Phillips curve, as done in Granville and Mallick (2010)

$$[5] \quad \pi_t = \psi \Delta y_t + \kappa \Delta e_t + \lambda \Delta DA_t + \rho \pi_t^0 + \mu_t$$

Domestic assets term suggests that if the currency does not change in response to changes in capital inflows, then an increase in money growth can contribute to generating inflation (π_t). We also include the oil price (π_t^0) in order take into account the external oil price shocks as a source of inflation pressures. Therefore substituting equation [4] into equation [5] gives

$$[6] \quad \pi_t = (\psi + \lambda \alpha) \Delta y_t - \gamma \lambda r_t + (\kappa - \lambda \eta) \Delta e_t - \lambda \Delta IR_t + \rho \pi_t^0 + (\lambda \nu_t + \mu_t)$$

The equation suggests inflation should go down as real interest rate increases; should rise as currency depreciates; and inflation can be reduced when international reserves increase by allowing currency to appreciate flowing capital inflows when the central bank does not sterilize the capital inflows. The negative effect of international reserves accumulation can be neutralised

⁶ Kalra (1998) suggest that a-priori the sign on expected depreciation is indeterminate and depends on whether broad money is defined to include or exclude foreign currency denominated deposits. The inclusion of broad money is defined to include foreign currency deposits. Therefore an expected depreciation in the exchange rate could induce a migration into foreign currency denominated assets hence the shift in the composition of broad money towards foreign currency denominated assets implying coefficients on exchange rate is positive. In contrast a shift to foreign currency contributing negative component to exchange rate changes.

by currency depreciation. The dominance of the latter over reserves accumulation can lead to inflation. The monetary policy authorities determine the interest rates, increasing it to lower inflation rate via monetary contraction and giving little weight to exchange rates hence establishing a trade off between the exchange rate and inflation. For an open economy, the Taylor rule can be written for the unobservable equilibrium real interest rate to include exchange rates

$$[7] \quad r_t = \delta y_t + \phi(\pi_t - \pi^*) + \beta \Delta e_t$$

The parameters δ, ϕ and β give the size of the response of monetary policy measured by interest rate to output, inflation gap and changes from exchange rates. The interpretation of the reaction function suggests that real interest rate is increasing in the excess of inflation rate over the inflation target, in current output and exchange rate depreciation. Growth in money declines in equation [3] as real interest rates increase, hence stabilising inflation rate in Phillips equation. Granville and Mallick (2010) suggest that Fisher effect holds when the real interest rate should not change in response to changes in inflation. Alternatively the inflation rate can have one to one positive effect on the nominal interest rate. Also the exchange rate depreciations can produce an increase in real interest rate and their simultaneous inclusion will therefore disentangle their effects on the real interest rate .

This paper derives the aggregate supply equation which is formulated following the open economy Phillips curve. This formulation defines the inflation rate in terms of foreign exchange reserves, oil price shocks, real interest rate, exchange rate and output. The focus of this analysis differs from the research aim done by Granville and Mallick (2010). We impose restrictions on the identified variables in the aggregate supply equation for a different purpose to that of Granville and Mallick (2010). The paper assesses which policy shocks between different exchange rate shocks and inflation rate shocks can achieve positive real output growth rates given variables in the inflation equation in South Africa and the central bank maintenance of price stability remaining essentially.

4. Bayesian VAR model and identification

4.1. VAR model

We estimate the inflation shocks and three exchange rate depreciation shocks in South Africa in the framework of VAR. The sign identification starts with the estimation of a reduced-form VAR equation [9]. For simplicity we omitted the intercept term and dummies.

$$[8] \quad Y_t = BY_{t-1} + u_t$$

Where Y_t is an $n \times 1$ vector of data series at date $t = 1, 2, \dots, T$ where $B = [B_1, B_2, \dots, B_p]$ is the vector of matrix of lagged coefficients and u_t is the one-step ahead prediction error and the

variance-covariance matrix is Σ . Assuming independence of fundamental innovations, we need to find matrix A which satisfies $u_t = A\varepsilon_t$. The j^{th} column of A , that is α_j represents the immediate impact on the variables of the j^{th} fundamental shock equivalent to one standard deviation in size on the n -endogenous variables in the system. Hence the variance-covariance is given by $\Sigma = E(u_t u_t') = AE(\varepsilon_t \varepsilon_t')A' = AA'$. To identify A , we need at least $n(n-1)/2$ restrictions on A . The reduced form disturbance are orthogonalised by Cholesky decomposition, which use recursive structure on A making it lower triangular matrix.

4.1.2 Pure sign restriction

We adopt the Bayesian sign restriction approach (see Uhlig (2005) Mountford and Uhlig (2009), Fratzscher et al (2010)) to identify the VAR model through imposing sign restrictions on the impulse responses of a set of variables. The identification here searches over the space of possible impulse vectors $A_i \varepsilon^i$ to find those impulses responses which agree with the sign restrictions. The aim is to find impulse vector a where $a \in R^n$, given that there is an n -dimensional vector q of unit length so that $a = \tilde{A}q$ where $\tilde{A}\tilde{A}' = \Sigma$ and \tilde{A} is a lower triangular Cholesky factor of Σ .

The first part of section 5 reports results of individual identified fundamental shocks. We show that the impulse responses for n -variables up to horizon S can be calculated for a given impulse vector a_j , after estimating coefficients in B using the ordinary least squares. The unique impulse response function is given by equation [8] as done in Fratzscher et al (2010)

$$[9] \quad r_s = [1 - B]^{-1} a_j$$

The r_s denotes the matrix of impulse responses at horizon S . Sign restrictions are imposed on a subset of the n -variables over horizon $0, 1, \dots, S$ such that the impulse vector a_j identifies the particular shock of interest. The estimation of impulse responses is obtained by simulation. Given the estimated reduced form VAR, we draw q vectors from the uniform distribution in R^n divided it by its length to obtain a candidate draw for a_j and calculate its impulse responses while discarding any q where the sign restrictions are violated. The estimation and inferences is done as explained below. In the sign restriction approach a prior is formed for the reduced form VAR model. Using the Normal-Wishart in (B, Σ) as the prior implies the posterior is the Normal-Wishart for (B, Σ) times the indicator function on $\tilde{A}q$. The indicator function separate draws which satisfied the sign restriction from those which fail to do so. A joint draw from the posterior of the Normal-Wishart for (B, Σ) and draws from the unit sphere are drawn from posterior distribution to get a candidate q vectors. We use the draws from the posterior to calculate the Cholskey decomposition as important computational tool rather than shocks identification tool. From each q draw we compute the associated a_j vectors and impulses responses and these impulses are subject to further selection. For those impulse responses which

satisfy the sign restrictions the joint draws on (B, Σ, a) are stored otherwise they are discarded. The error bands are calculated from draws kept from 1000 draws which satisfy the sign restrictions. As such, this first part focuses on estimation of one shock.

The second part of section 5 report the impulse responses of two identified fundamental shocks, that is, $k = 2$. The above approach is extended to include two shocks. As such, we characterize the impulse matrix $[a^{(1)}, a^{(2)}]$ as of rank 2 rather than all of A in robustness test. We impose the restrictions based on economic prior's expectations on the impulse responses together with restrictions that ensure orthogonality of the fundamental shocks. By construction the covariance between fundamental shocks $\varepsilon^{(1)}_t, \varepsilon^{(2)}_t$ corresponding to $a^{(1)}, a^{(2)}$ is zero meaning that these fundamental shocks are orthogonal.

Hence any impulse matrix $[a^{(1)} \dots a^{(k)}]$ can be written as product $[a^{(1)} \dots a^{(k)}]q = \tilde{A}Q$ of the lower triangular Cholesky factor \tilde{A} of Σ with $k \times n$ matrix $Q = [q^{(1)} \dots q^{(k)}]$ of orthonormal rows $q^{(j)}$ such that $QQ' = I_k$. This is a consequence of noting that $\tilde{A}^{-1}\tilde{A}$ must be an orthonormal matrix for any decomposition $\tilde{A}\tilde{A}' = \Sigma$ of Σ . Denoting $a = a^{(s)}$ where $s \in \{1, 2, \dots, n\}$ represents a column of the impulse matrix. We also denote $q = q^{(s)} = \tilde{A}^{-1}a^{(s)}$ as the corresponding column of Q . Therefore the impulse responses for the impulse vector a can be written as a linear combination of the impulse responses to the Cholesky decomposition of Σ in a way described below. Denoting $r_{ij}(s)$ to be the impulse response of the j^{th} variable at horizon s to the i^{th} column of \tilde{A} , and the n -dimensional column vector $r_i(k) = [r_{1i}, \dots, r_{ni}]$. The n -dimensional impulse response r_{as} at horizon s of impulse vector $a^{(s)}$ is given by

$$[10] \quad r_{as} = \sum_{i=1}^n q_i r_{is}$$

where q_i is the i^{th} entry of $q = q^{(s)}$. We identify $a^{(1)}, a^{(2)}$ using the appropriate sign restrictions $a^{(1)} = \tilde{A}q^{(1)}$ and $a^{(2)} = \tilde{A}q^{(2)}$ at the same time jointly impose orthogonality conditions in the form $q^{(1)}q^{(1)'} = 0$ and $q^{(2)}q^{(2)'} = 0$. In general a joint draw is taken from the posterior of the Normal-Wishart for (B, Σ) to obtain the candidate q vectors. Each draw for q that satisfy the above restrictions is kept otherwise it is discarded. The error bands are calculated from draws stored from 10000 draws which satisfy the sign restrictions. Pure sign restriction approach makes explicit use of restrictions that researchers use implicitly and are therefore agnostic.

We use the penalty function approach to test the robustness of the results from both single shocks. Moreover we replace reserves excluding gold with foreign exchange. The penalty function developed by Uhlig (2005) rewards responses that are consistent with the restrictions

and penalizes heavily those violating the restrictions. Unlike the pure sign restriction approach, the penalty function uses additional restrictions which lead to possible distortion of the true direction of the responses from the imposed sign restrictions. We use pure sign restrictions in main body of the paper and penalty function approach in robustness analysis.

4.2. The empirical model

We adopted Granville and Mallick (2010) sign restriction identification approach which is robust to both non-stationarity of the series including breaks. The exchange rate and inflation rate shocks effects are restricted to last at least $K=6$ months. We argue that the monetary policy authorities reaction to these variables has implications on the output stabilisation outcomes. Strict inflation targeting does not attach any weight to output gap stabilisation. The instrument is set such that conditional inflation forecast equals the inflation target. Any shocks causing deviations between the conditional inflation forecast and the inflation target are met by an instrument adjustment that eliminates the deviation. In contrast, flexible inflation targeting attaches a positive weight on output gap stabilisation, interest rate, real exchange rate and inflation. The policy instrument under flexible inflation targeting is adjusted such that conditional inflation forecast approaches the long run inflation gradually, minimising fluctuations on output gap, exchange rate and interest rates. The larger the weight attached on output gap stabilization, the slower the adjustment of conditional inflation forecast towards the long run inflation target.

The role of exchange rate in an open economy framework is important in the monetary transmission mechanism. Real exchange rates affect aggregate demand channel of the monetary transmission of monetary policy. It affects the relative prices between domestic and foreign goods and foreign demand for domestic goods. The direct exchange rate channel for monetary policy transmission, affects inflation through domestic price of imported goods and intermediate inputs, which are components of consumer price inflation. In addition, it affects nominal wages via the effect on inflation on wage setting, the foreign demand for domestic goods which impact on the aggregate demand for domestic goods. Based on these conclusions we identify two main shocks, namely; the exchange rate depreciation shocks, which has both inflationary effects and growth effects in the economy, and the inflation shock, by imposing three sign restrictions for each shock, in the following way:

Table 1. Sign restrictions for inflation and exchange rate shock

| | r_t | π_t | Δe_t | Δy_t | ΔIR_t | π_t^0 |
|-----------|-------|---------|--------------|--------------|---------------|-----------|
| Inflation | ? | + | ? | ? | + | + |
| Rand | ? | ? | + | ? | + | + |
| REER | ? | ? | - | ? | + | + |
| NEER | ? | ? | - | ? | + | + |

NB. The ? indicates the variable was left unrestricted whereas (-)/+ implies (negative)/ positive effects

Firstly, the sign restrictions imposed suggest that, the oil price does not decrease as an exogenous positive shock. Secondly, the change in foreign exchange reserves does not decrease in response to oil inflation or exchange rate depreciations. The study uses three exchange rates. The positive sign on the Rand price of one dollar implies depreciation of the rand. However, the negative sign on both the real effective exchange rate and nominal effective exchange rate imply depreciation. Thirdly, the rand per dollar exchange rate change will not decline in response to its own positive shock whereas both nominal and real effective exchange rates should not rise after depreciation shock. We assume these exchange rate depreciations should occur due to own innovations and changes in reserves and oil price inflation.

The overall inflation does not decline in response to its own shock. South African foreign exchange reserves excluding gold accumulation increased since the adoption of the inflation-targeting framework. Therefore, a monetary or inflation shock can emerge from changes in reserves growth or due to oil price inflationary shock. Domestic currency depreciation makes domestic exports cheaper relative to imported goods and can lead to rising inflation rates. Higher demand for domestic goods partly due to increased export demand can increase industrial production. However we refrain from prejudging this outcome and let impulse responses reveal it. Moreover, exchange rate changes can be either an appreciation or depreciation depending on the direction of change. These asymmetric outcomes are equally likely under the pure sign restriction. However, this method keeps those impulse vectors which satisfy the imposed sign restriction while discarding those violating them in response to a unit shock innovation.

4. The Data

The study uses monthly data from January 2000 to January 2010 under the inflation-targeting regime.⁷ We use six variables namely, the growth in foreign exchange reserves excluding gold, output growth approximated by manufacturing production growth, inflation rate, growth in nominal rand, nominal effective exchange rate (NEER), real effective exchange rate (REER), growth in oil price index and real interest rate. We use data extracted from the International Monetary Fund IFS database. We use three measures of exchange rate namely, the nominal rand per US dollar (R/\$), NEER and REER in separate estimations. The real interest rate equals the difference between nominal interest rate and expected inflation rate. We calculate the expected inflation rate using the methodology in Davidson and Mackinnon (1985).⁸ Both the inflation rate and expected inflation rate display similar trends in figure A1 in Appendix A. We calculated the

⁷ The percentage calculated using the year on year percentage changes approach alters the starting period. The estimation period starts from January 2001 rather 2000. However we need the observation from 2000.

⁸ We adopted Davidson and Mackinnon (1985) method. The procedure first calculated the weighted inflation rate using this following equation. Weighted inflation $\pi_t^w = 0.2 \times \pi_{t-1} + 0.3 \times \pi_{t-2} + 0.3 \times \pi_{t-3} + 0.2 \times \pi_{t-4}$. Then regress inflation (π_t) on the constant,

weighted inflation rate (π_t^w) and trend. The forecast inflation rate from the regression becomes the expected inflation. The real interest rate

(r_t) is given by difference between nominal interest rate (i_t) and expected inflation (π_t^e) i.e $r_t = i_t - \pi_t^e$

growth rates as year on year percentage changes.⁹ A positive increase in REER and NEER represents appreciation respectively and domestic currency depreciation.

Figure 1 shows the variables annual percentage changes except the real and nominal interest rates which are in levels. For most periods under review, the manufacturing index has grown by nearly 5% between 2003 and 2008 and contracted by 16% in 2009 due to recession. The consumer price inflation, nominal interest rates and expected inflation rates variables move closely together with the regimes of lower rates of changes and higher rates of changes coinciding on same periods. Higher inflation rates, expected inflation rates and nominal interest rates occurred in 2002-2003 and 2007-2008 with lower rates in 2004-2007 and after 2009. The nominal interest rates remained above the 6% lower bound whereas the real interest rates remained positive for most periods except in 2008 and 2009 showing transitory negative values.

Oil price inflation displayed huge upward and downward movements between 2007 and 2010. In annual terms, the oil price increased by more than 50% in 2008 and declined by nearly 75% from the fourth quarter of 2008 to the second quarter of 2009. In the last quarter of 2009, it increased by nearly 50% due to low base effects in the previous year. Reserves excluding gold and foreign exchange growth rate were negative before 2003 reflecting the period in which the South African Reserve Bank closed the forward book. Moreover, higher growth rates between 2004 to early 2005 reflected low base effects in previous years, thereafter Central Bank gradually continued to acquire reserves. All three exchange rates depreciations tend to be persistent in the periods; 2000 to 2002, mid-2006 to early-2007, late-2007 to early-2009. The exchange rates appreciation periods includes the periods of late-2002 to early-2005 and from second quarter of 2009.

⁹ For example, the inflation rate (π_t) is calculated using formula $\pi_t = 100 \times (\log(cpi_t / cpi_{t-12}))$

Figure 1. Plot of variables

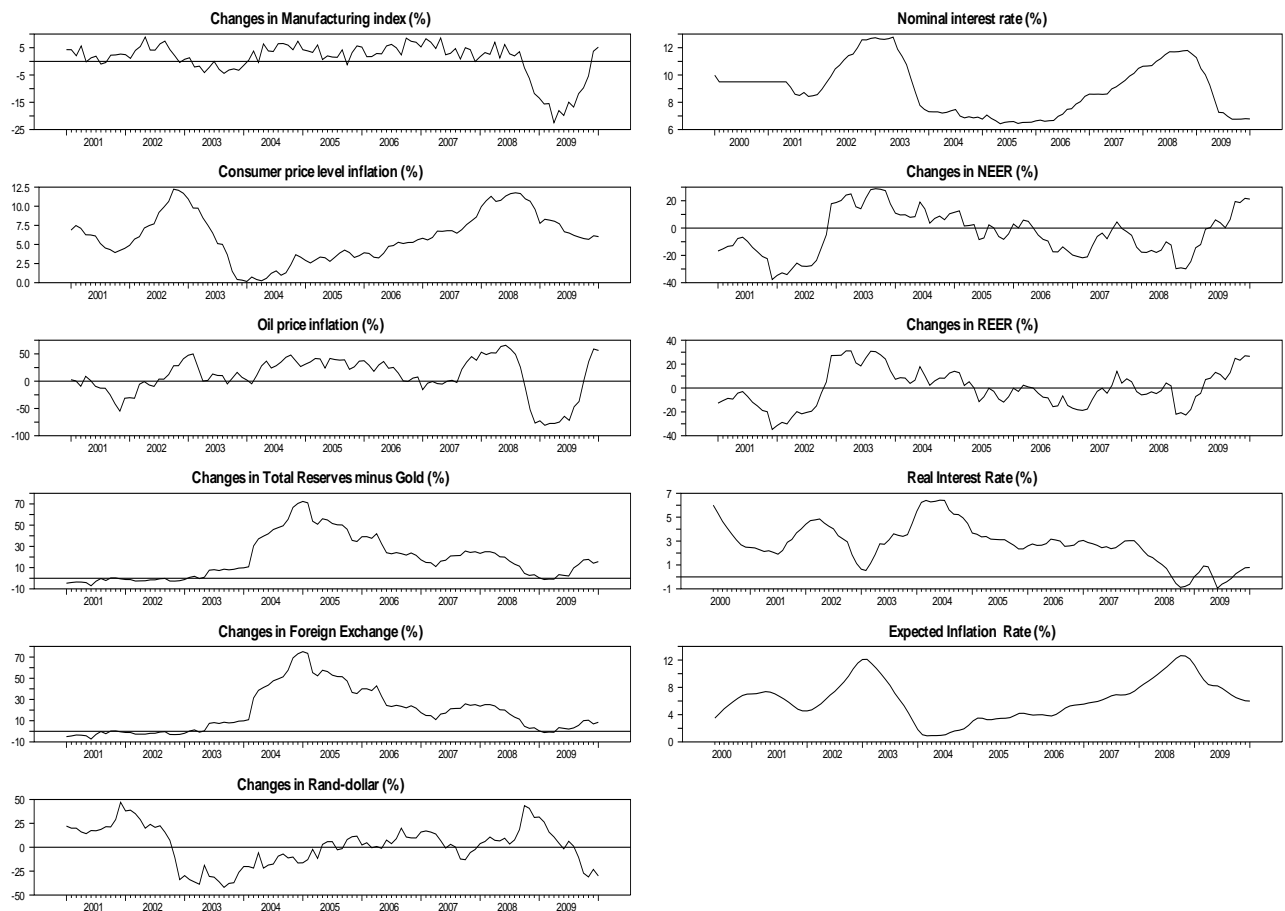


Table 2 shows the descriptive statistics of all variables, in particular the mean, standard deviation, minimum and maximum values. Oil price inflation has the highest standard deviation value indicating that it is the most volatile variable with both the minimum and maximum growth rate exceeding 65%. All the three exchange rate measures show that the exchange rates deviate from their means by 15-21%, which is higher than deviations of both inflation, expected inflation and interest rates. The reserves excluding gold as well as foreign exchange show deviations from the mean growth rates of about 20%. These percentage deviations from both reserves and foreign exchange mean growth rates exceed percentage deviation of CPI inflation rate, nominal interest rate, real interest rates and expected inflation rate. In terms of mean growth rates reserves excluding gold and foreign exchange experienced average growth rates of at least 18% which are the highest growth rates compared to all other variables possible indicating the active accumulation of both reserves and foreign exchange by the Reserve Bank. The growth in manufacturing volume index is extremely low and being less than 1% over the period and its deviation from the mean is nearly 7 possible reflecting huge negative effect of the recession in 2009.

Table 2. Descriptive statistics

| Variable | Mean | Std Error | Minimum | Maximum |
|--------------------------------|-------------|------------------|----------------|----------------|
| Nominal interest rate | 9.01 | 1.90 | 6.43 | 12.8 |
| CPI inflation rate | 5.99 | 3.13 | 0.16 | 12.2 |
| Oil price index inflation rate | 8.94 | 35.0 | -80.8 | 65.7 |
| Rand | 1.55 | 20.6 | -42.0 | 47.1 |
| NEER | 3.98 | 16.5 | -37.7 | 28.8 |
| REER | 0.23 | 15.7 | -34.7 | 31.1 |
| Manufacturing Index | 0.89 | 6.43 | -22.5 | 8.90 |
| Reserves excluding gold | 18.4 | 20.2 | -7.13 | 72.4 |
| Foreign exchange | 18.4 | 21.0 | -7.27 | 75.0 |
| Real Interest rate | 2.75 | 1.73 | -0.95 | 6.43 |
| Expected inflation rate | 6.24 | 2.95 | 0.89 | 12.6 |

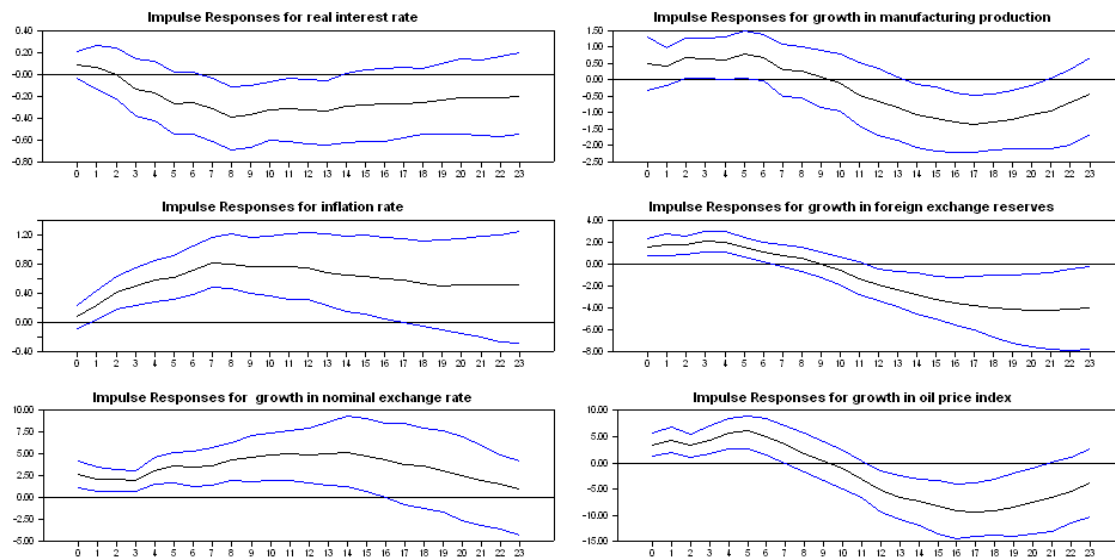
NB. All the variables excluding Nominal interest rate, expected inflation rate and real interest rate are percentages in levels. The remaining variables represent percentage growth rates.

6. Results

We compare the effects of exchange rate depreciation shocks to those of inflation shocks on how they influence real output growth rates using VAR sign restriction approach with 6 lags. We restrict shock effects to last at least $K=6$ months (see Uhlig (2005); Mallick and Rafiq (2008)). The stabilization of output, employment or the real exchange rate is a reason for hitting the inflation target at a longer horizon under flexible inflation targeting (Svensson 1997). Furthermore, the variability of the output, employment and real exchange rate and not their average levels are important. Hence this framework involves less policy activism and the gradual returning of the inflation rate back to the target rate which reduces the variability of output, employment and real exchange rate. The first part of the analysis presents results based on individual estimation of shocks following the Uhlig (2005) approach. The second part discusses the results based on Mountford and Uhlig (2009) approach which takes orthogonal property between fundamental shocks and impulse responses when two shocks are estimated together. We also perform three robustness tests using the penalty function, changing the horizon period in which shocks are expected to last from $K=6$ months to $K=9$ months and using foreign exchange amount rather than total reserves excluding gold. We use growth in nominal exchange rate denoting nominal rand per US dollar changes. We approximate real output by manufacturing output since it contributed 18% to country's GDP.

Figure 2. Exchange rate shocks

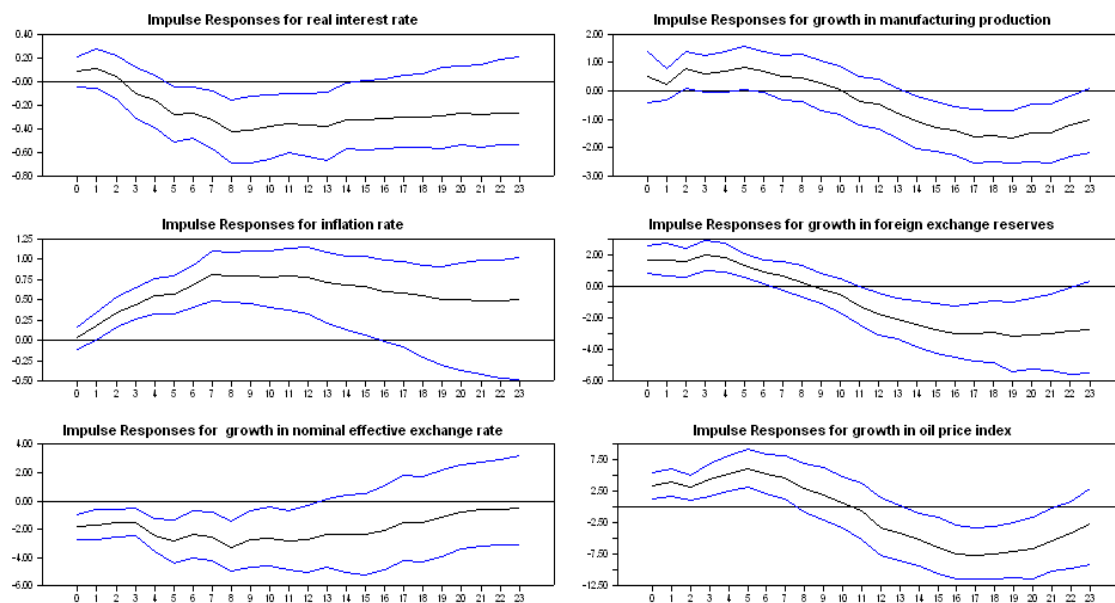
Rand depreciation shock



Impulse Responses with Pure-Sign Approach

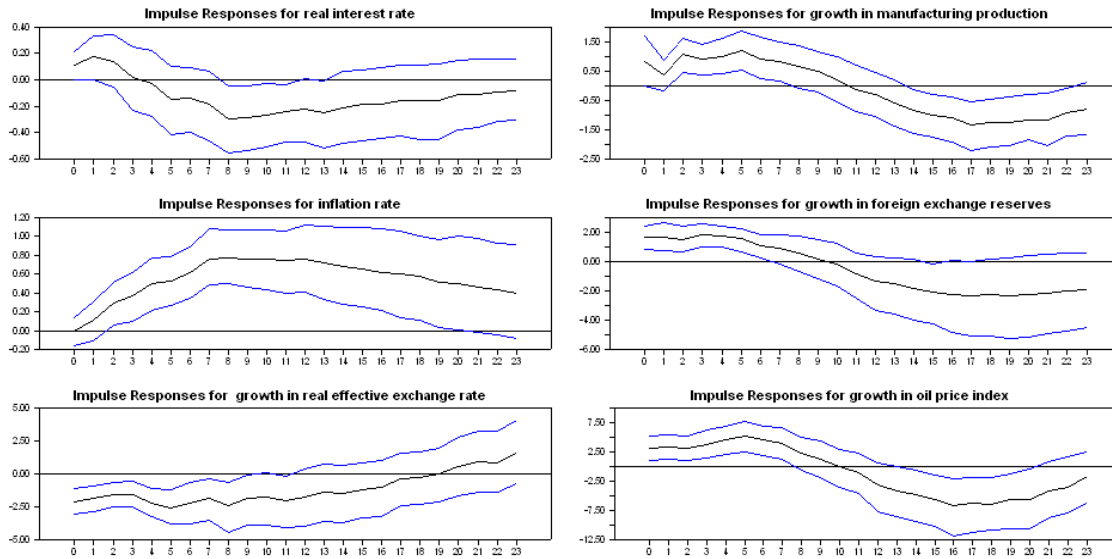
NB growth in nominal exchange rate refers to rand per US dollar changes

Nominal effective exchange rate depreciation shock



Impulse Responses with Pure-Sign Approach

Real effective exchange rate depreciation shock



Impulse Responses with Pure-Sign Approach

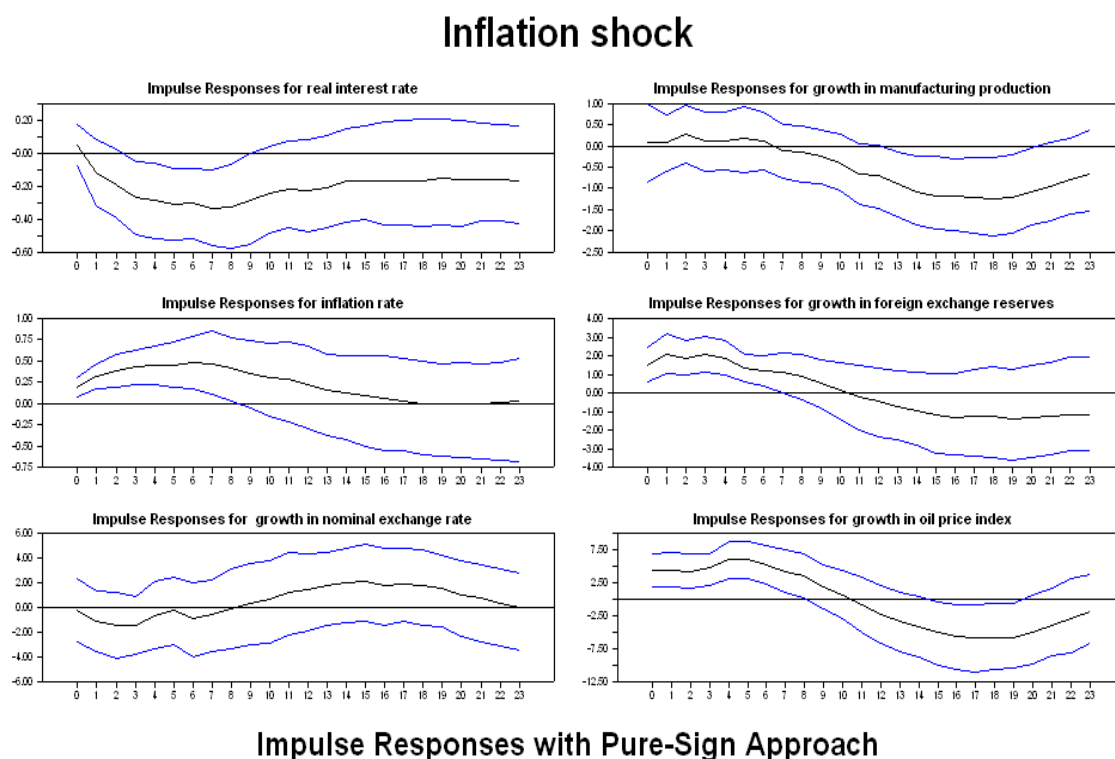
Figure 2 shows the responses to the nominal rand per US dollar, nominal effective exchange rate and real effective exchange rate depreciation shocks respectively. Consistent with economic theoretical predictions, inflation responds positively to currency depreciation across all measures of exchange rates. These three different exchange rates depreciations significantly increase inflation rate by a maximum of 0.8 percentage points in the seventh month. After 19 months, the inflation increase converges to 0.4 percentage points which is not significantly different from zero. Foreign reserves growth remains positive for 10 months exceeding the imposed six months (i.e. shock duration). Granville and Mallick (2010) suggest that high foreign exchange reserves and high real interest rates should appreciate domestic currency. However, we do not find significant evidence of the Rand appreciation in the long run.

All three exchange rates depreciations have a positive impact on output growth but this is significant for 8 months under the REER depreciation only. We suggest the volatile currency which fails to self-correct resulting in persistent appreciations in certain periods as in figure 1, under inflation targeting may weaken output growth. Moreover, we notice that the manufacturing growth and oil price inflation weakened in the long run. This could be due to delayed exchange rate appreciations after a depreciation which erodes the manufacturing competitiveness whereas persistent inflation pressures had negative effects on real output as suggested by Friedman (1977). It is plausible for oil price inflation to decline in long-run despite South Africa being a small open economy which cannot influence world prices. Mishkin (2007) argues that in the long run the country which becomes more productive relative to other countries expects its currency to appreciate. Oil price inflation should decline following such domestic currency appreciation.

The impulse responses between output and reserves show close co-movements. Concurrent declines in reserves and manufacturing could be explained using equation [2] indicating that reserves accumulation is also driven by developments in manufactured exports. Thus depreciation which stimulates growth in manufactured output improves the accumulated foreign reserves. Moreover, foreign reserve accumulation could result from physical accumulation of reserves and monthly revaluations. Persistent exchange rate appreciations or depreciation alter the amount of reserves in any point in time during revaluation process. The lack of significant evidence of currency appreciation suggests the dominance of manufacturing exports over exchange rate effects in influencing reserve accumulation.

The inflation dynamics in response to an inflation shock are less persistent compared to those arising from exchange rate shocks. Granville and Mallick (2010) argue that the New Keynesian theoretical models do not predict a sufficient degree of inflation persistence after a monetary shock. They suggest that inflation should rise and recede to zero quickly rather than dying slowly as predicted by empirical literature. In addition, inflation rises for some extended periods in response to an exchange rate depreciation and the increase is not significant after 18 months under the NEER and REER depreciation while it remains persistently so under nominal rand depreciation.

Figure 3: Inflation shocks



In figure 3, the real interest rates fall significantly and retreat to pre-shock levels. This suggests that with a change in inflation rate, the nominal interest rate is changing marginally less than the change in inflation. Monetary policy conducted in forward looking manner, requires interest rates smoothing over time in anticipation that inflation would eventually fall within the target band. In long run, the Fisher effect holds as the change in real interest rate is not significantly different from zero. This implies that the nominal interest rate increased by the similar change in inflation rate. We conclude that monetary policy is effective in controlling inflation over the long horizon.

Growth in manufacturing output remains significantly positive for long periods in response to REER depreciation relative to both rand and nominal effective exchange rate depreciations. Furthermore, similar to the rand and nominal effective exchange rate, the results suggest that real effective exchange rate depreciation contribute to inflationary pressures. However, the Central Bank increases interest rate to lower the inflation rate in the long run. This indicates that policies which hugely affect the pricing behaviour to depreciate real effective exchange rate aimed to improve competitiveness, have positive real effects on output growth.

6.1.1 Results from estimating two shocks using orthogonality assumption

We assess the impacts of the exchange rate and inflation shocks under the orthogonality assumption to avoid sequential estimation and ordering problems. Rafiq and Mallick (2008) argued that sequentially estimation procedure may lead to sampling problems suggesting the sequence of shocks would affect the results. Hence, we draw the two vectors simultaneously to eliminate any sampling uncertainty created by such sequentially sampling draws. Furthermore, the order in which the shocks are established can have implications for the final results. Our structural shocks are orthogonally drawn and impulse vectors subsequently derived which makes the ordering of these shocks less important for the results. These results are robust to changes in the order of the two shocks.

Figure 4. Comparison of exchange rate depreciation shocks and inflation shocks

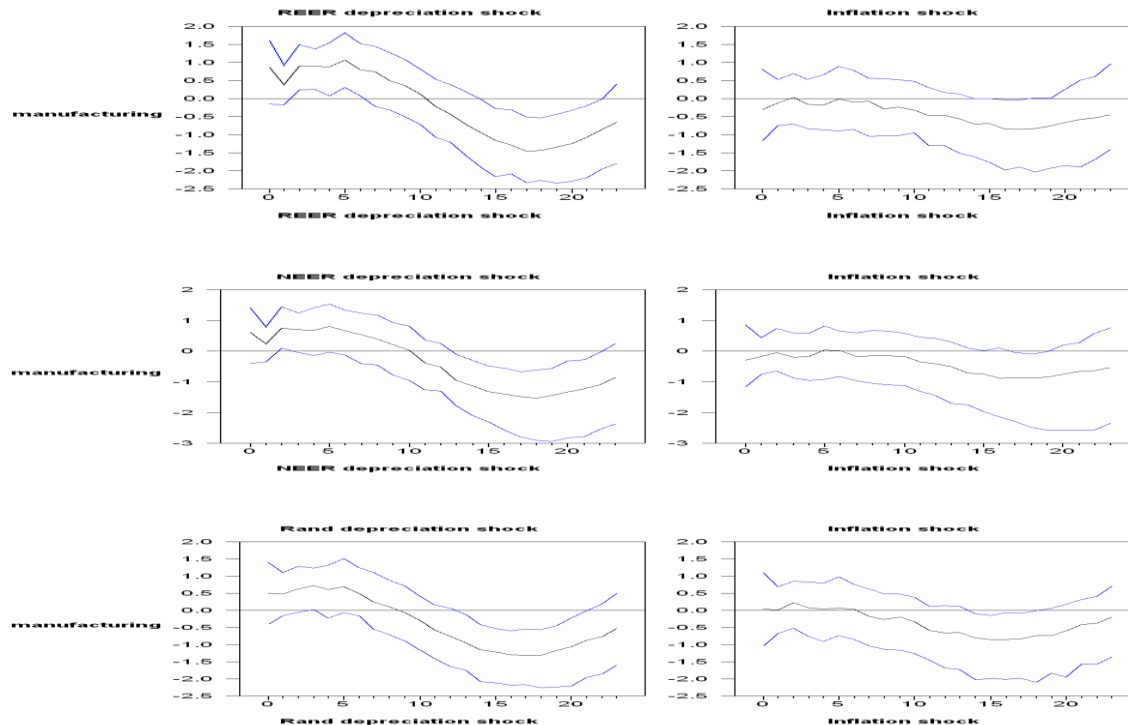


Figure 4 shows the paired effects of shocks on manufacturing for comparative purposes. Moreover all impulse responses are presented in Appendix B. These results do not differ from those estimated using individual shocks. Similarly, the inflationary shocks have an insignificant stimulus on manufacturing growth. In contrary, the real effective exchange rate leads to significant growth in manufacturing for at least 7 months whereas the rand-dollar and nominal effective exchange rates have no such effects on manufacturing output growth rate. Thus the previous conclusions are robust to the orthogonality and robust to ordering suggesting these impulse responses do not contain sampling uncertainty created by sequentially ordering of the shocks.

6.1.2. Variance decomposition analysis

Table 3. Variance decomposition of all exchange rate shocks and inflation shocks on manufacturing growth

| Steps | NEER | RAND | REER | INFNEER | INFRAND | INFREER |
|-------|-------|-------|-------|---------|---------|---------|
| 1 | 8.7% | 8.9% | 10.7% | 8.8% | 8.7% | 8.6% |
| 2 | 11.0% | 10.9% | 12.7% | 10.9% | 11.3% | 10.1% |
| 3 | 12.5% | 12.4% | 13.6% | 11.9% | 11.8% | 12.1% |
| 4 | 12.6% | 12.5% | 14.0% | 12.0% | 12.1% | 12.6% |
| 5 | 13.2% | 13.2% | 14.3% | 12.5% | 12.4% | 13.0% |
| 6 | 13.4% | 13.3% | 14.8% | 12.4% | 12.6% | 13.2% |
| 7 | 13.7% | 13.4% | 14.9% | 12.5% | 12.9% | 13.4% |
| 8 | 13.6% | 13.5% | 15.0% | 12.6% | 13.4% | 13.5% |
| 9 | 13.9% | 13.8% | 15.2% | 12.6% | 13.5% | 13.6% |
| 10 | 14.2% | 14.1% | 15.3% | 12.7% | 13.6% | 13.7% |
| 11 | 14.4% | 14.3% | 15.3% | 13.0% | 13.7% | 14.0% |
| 12 | 14.5% | 14.7% | 15.5% | 13.2% | 13.8% | 14.2% |
| 13 | 14.9% | 15.1% | 15.6% | 13.3% | 14.3% | 14.3% |
| 14 | 15.0% | 15.2% | 15.6% | 13.6% | 14.5% | 14.5% |
| 15 | 15.0% | 15.7% | 15.4% | 13.8% | 14.7% | 14.7% |
| 16 | 15.2% | 15.7% | 15.4% | 13.9% | 14.8% | 14.8% |
| 17 | 15.4% | 15.9% | 15.4% | 14.0% | 14.9% | 15.0% |
| 18 | 15.6% | 15.9% | 15.5% | 14.2% | 14.9% | 15.1% |
| 19 | 15.8% | 16.0% | 15.6% | 14.5% | 14.9% | 15.2% |
| 20 | 16.1% | 16.0% | 15.7% | 14.6% | 15.0% | 15.1% |
| 21 | 16.2% | 15.9% | 15.7% | 14.7% | 15.1% | 15.2% |
| 22 | 16.3% | 15.9% | 15.8% | 14.8% | 15.2% | 15.2% |
| 23 | 16.5% | 16.0% | 15.7% | 14.8% | 15.2% | 15.2% |
| 24 | 16.5% | 16.0% | 15.7% | 14.8% | 15.2% | 15.4% |

NB Inflneer, inflrand and inflreer refers to inflation shocks estimated using nominal effective exchange rate (NEER), rand dollar exchange rate and real effective exchange rate (REER). Steps ahead refers to horizons in months.

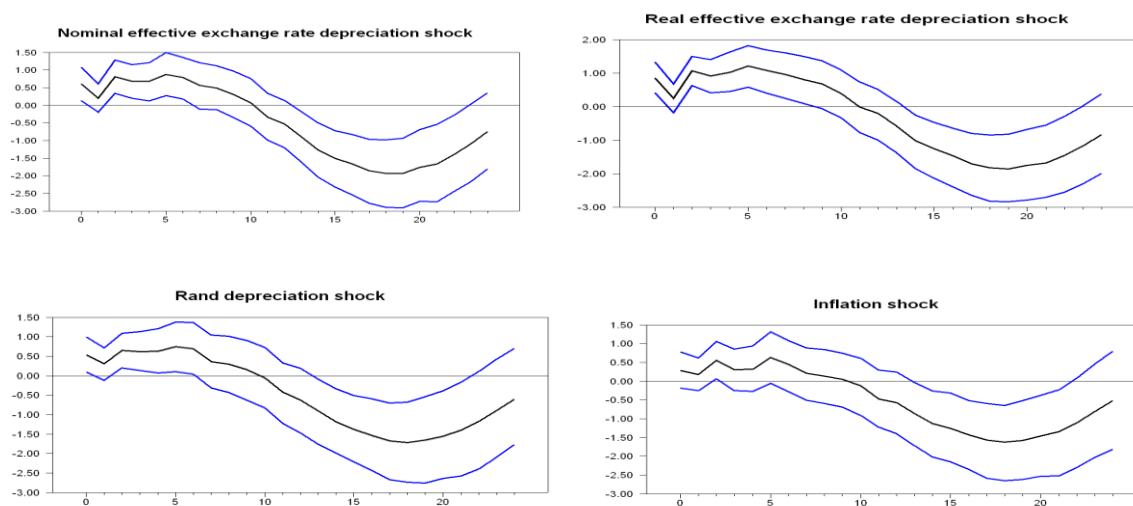
Table 3 shows the variance decompositions of different exchange rate shocks and the various inflation shocks estimated under three exchange rates. The variance explained by inflation shocks is lower than the corresponding variability explained by exchange rate shocks over all horizons. Amongst these three exchange rates, real effective exchange rate (REER) induces more variability in manufactured output in 14 months relative to rand exchange rates and 17 months relative to NEER. Moreover, the REER long run values are lower than other exchange rate long run values.

6.1.3 Robustness analysis

This section examines robustness of the earlier findings using penalty function, changing horizons for which shocks are expected to last and using foreign exchange under orthogonality assumptions. Figure 5 shows manufacturing impulse responses from the penalty function

confirming the findings from pure sign restriction approach. However we report all impulse responses from the penalty function in Appendix C. The error bands from the penalty functions look qualitatively similar to pure impulse responses; however these magnitudes are larger with error bands considerably much sharper. The penalty function searches for large initial reaction of exchange rate and inflation shock separately. The additional restrictions imposed in the penalty function introduce some distortion in pure sign restriction results. The findings suggest that the real effective exchange rate depreciation outperforms the nominal rand depreciation and nominal effective exchange rate depreciation under the same constraints by achieving higher growth rates. Output grew by nearly 1%, which is larger than growth rates achieved under both nominal rand and nominal effective exchange rates shocks. Under the inflation shocks, no significant output growth rates are achieved under same constraints. These findings are therefore robust.

Figure 5 All exchange rate depreciation shocks and inflation shocks from penalty function



Uhlig (2005) showed that results could be sensitive to periods imposed on restrictions in shock duration. Hence, our second approach tests the robustness of the earlier findings by increasing the horizons for which shocks effects are expected to last from $K=6$ months to $K=9$ months. The manufacturing impulse responses to exchange rate depreciation and inflation shocks are compared in figure 6. Similar to preceding findings we conclude that real effective exchange depreciation outperforms all other shocks. Additional figures (not shown here) confirm that the inflation shocks are not growth enhancing under all different exchange rate measures. This confirms these results are robust to change in horizon periods in which effects were expected to last.

Figure 6. Effects of exchange rate and inflation shocks on manufacturing for $K=9$ months

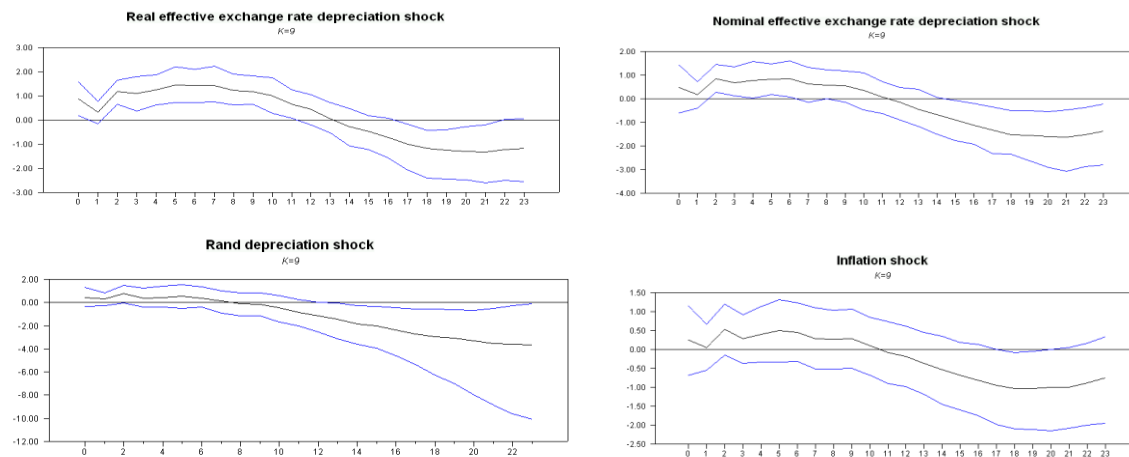


Figure 7. Comparison of all exchange rate depreciation shocks and inflation shocks using foreign exchange definition

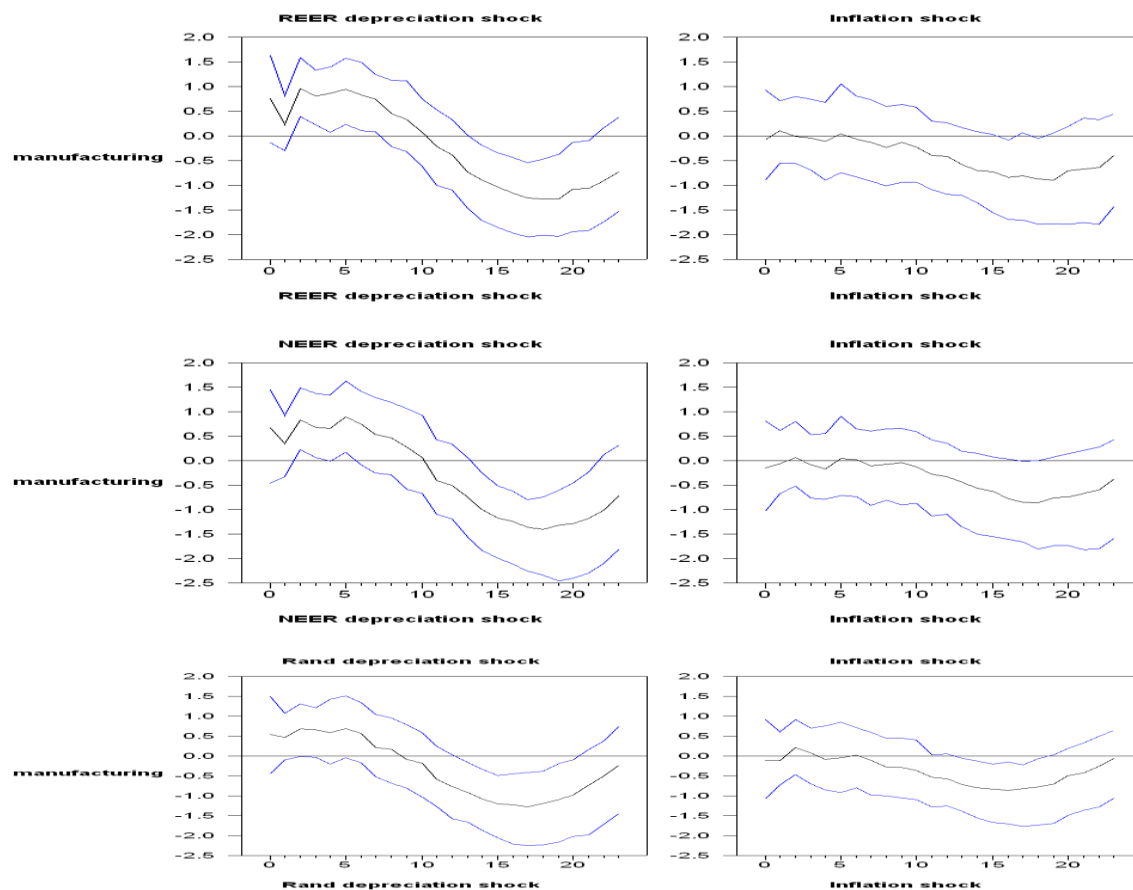


Figure 7 depicts the effects of exchange rate and inflation shocks on manufacturing under the third robustness test using the foreign exchange rather than the reserves minus gold. The estimations take orthogonality conditions into consideration between the fundamental shocks and

impulse responses of two shocks. The full results are attached in the Appendix D. Similarly, the real effective exchange rate (REER) depreciation leads to significant manufacturing growth compared to the rand-dollar and nominal effective exchange rate. Moreover, we reach the same conclusion (results not shown here) using the foreign exchange when shocks are assessed individually. Overall, the findings in this paper suggest the results are robust to change in definition of reserves and orthogonality assumption.

7. Conclusion

This paper investigates the relationship between real interest rate, inflation and exchange rate shocks in an environment of foreign reserves accumulation and oil price inflation, in South African inflation-targeting regime. We find significant evidence showing that the real interest rate reacts negatively to the inflation rate shocks. However this reaction is not significantly different from zero in longer horizon suggesting that the Fisher effect holds in the long run. This indicates both the nominal interest rate and inflation rate have increased by nearly the same magnitudes confirming the effectiveness of monetary policy in the long run to both shocks. Evidence from inflation shocks suggest that the monetary policy authorities' loss function paid more attention to bringing inflation towards the inflation target and less or no weight attached on output stabilisation. Thus strict inflation targeting approach is not compatible with significant real output growth. In contrast, we find that the REER depreciation has significant growth enhancing ability relative to other shocks. The inflationary effects from exchange rate depreciations are significantly dampened through monetary policy tightening. We find that under the flexible inflation targeting framework giving more weight to the real effective exchange rate results in significant real output growth. In policy terms, this implies focusing more on the exchange rate which deals with competitiveness relative to trading partners in an environment of reserves accumulation and uncertain high oil prices. Even under such circumstances monetary policy manage to control the inflation pressures associated with such a shock.

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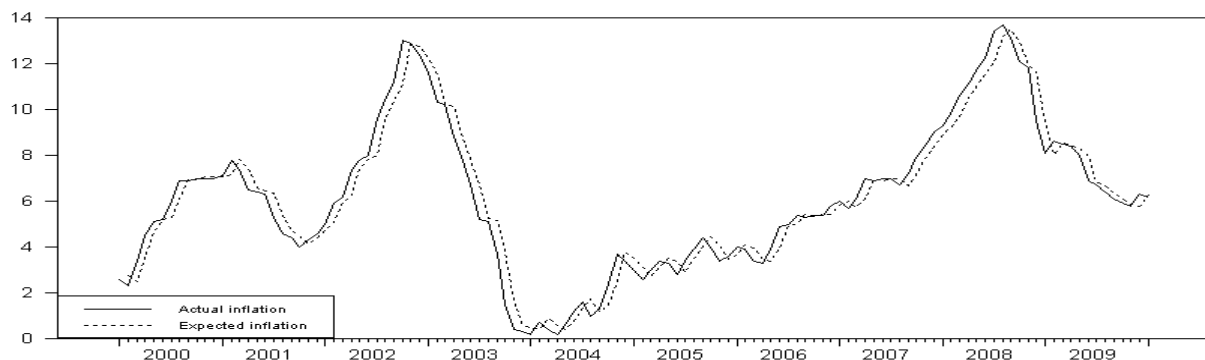
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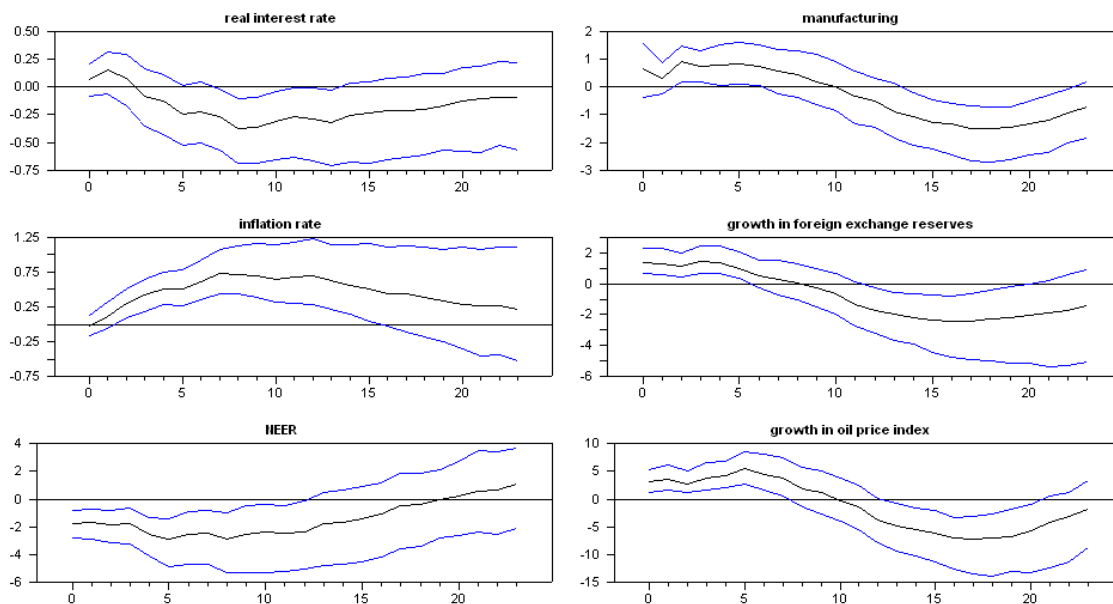
Appendix A

Figure A1: Inflation and Inflation expectation graph

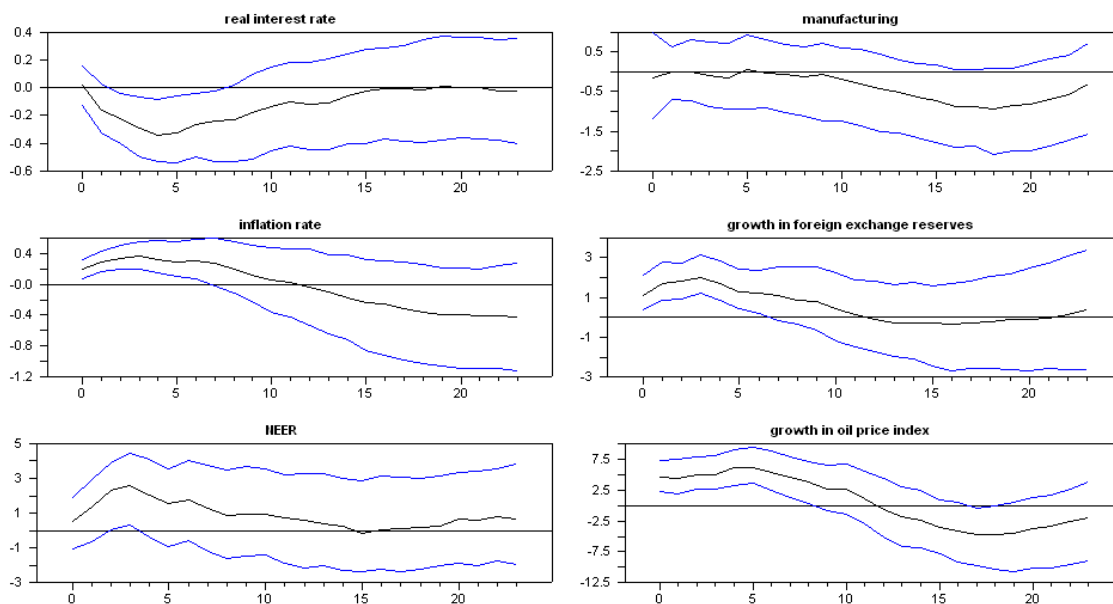


Appendix B . Results from orthogonality assumption

Figure B1. NEER depreciation and inflation shocks

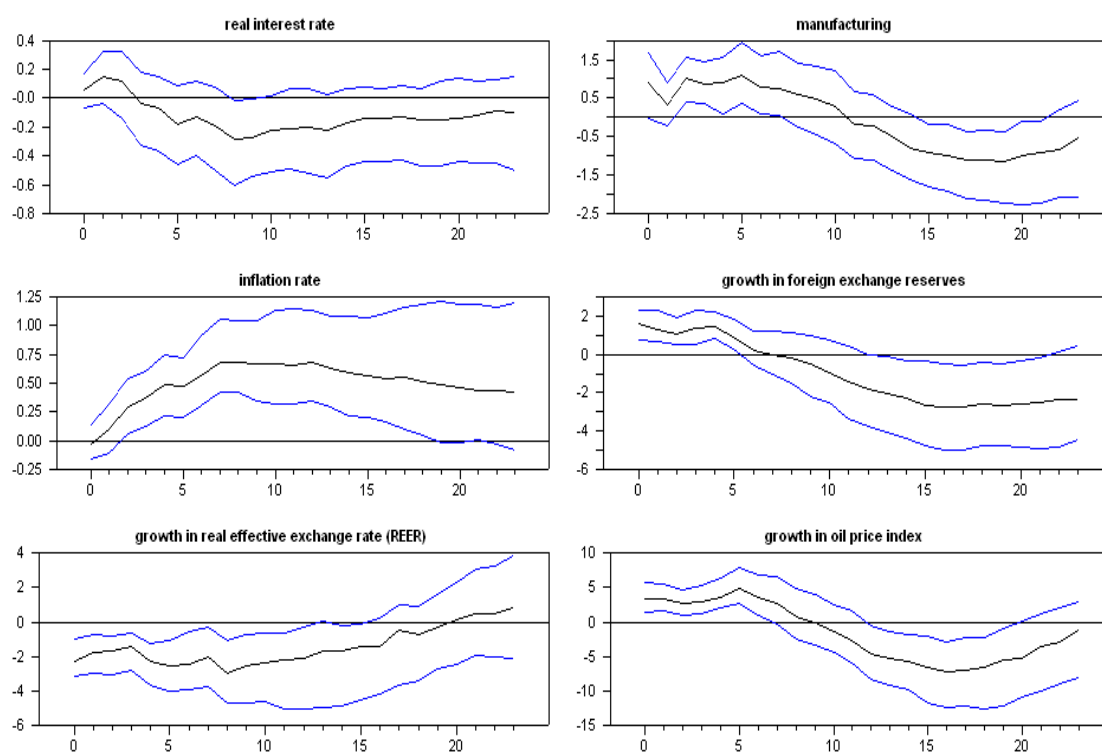


Responses to NEER depreciation shock

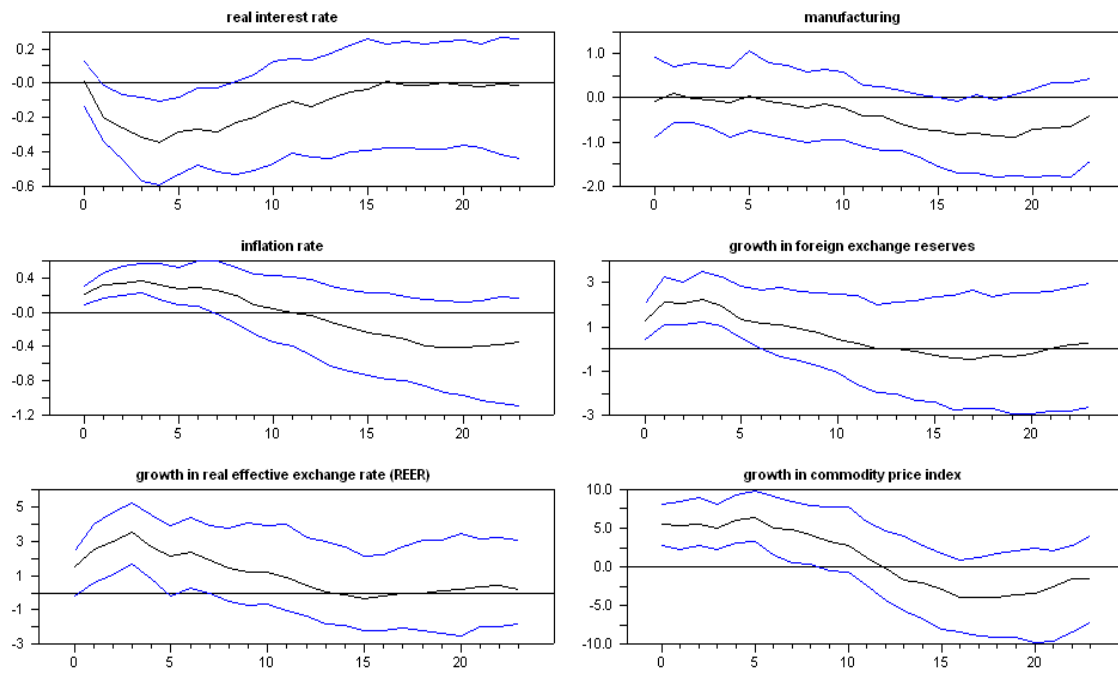


Responses to Inflation shock

Figure B2. REER depreciation and inflation shocks

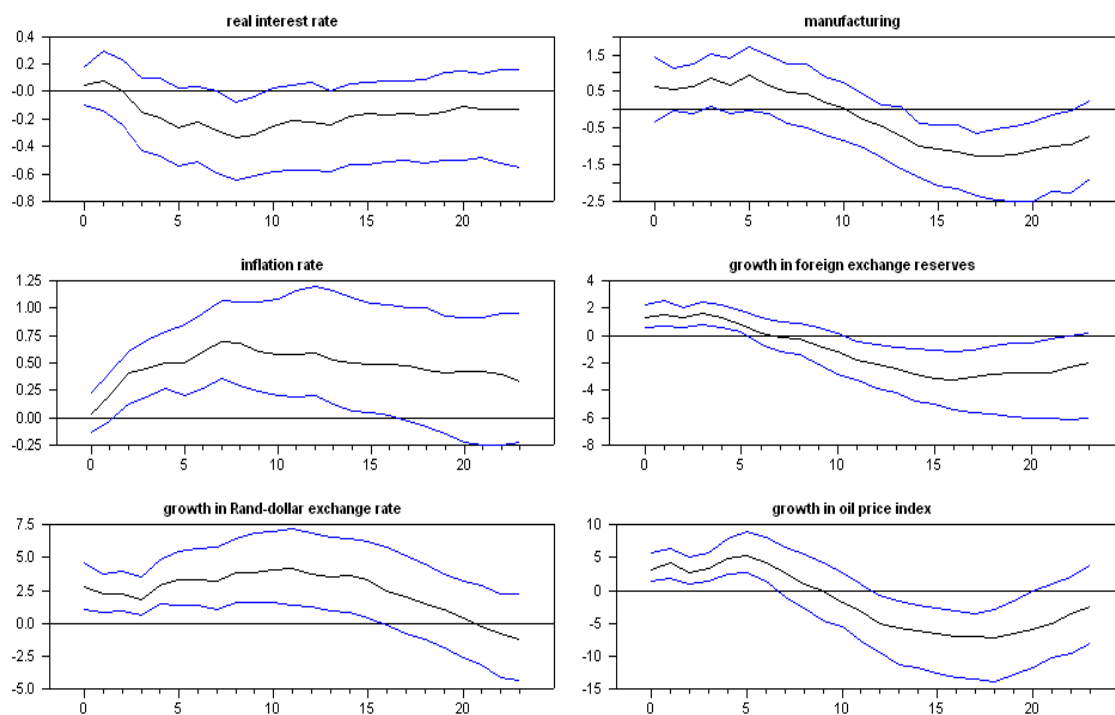


Responses to REER depreciation shock

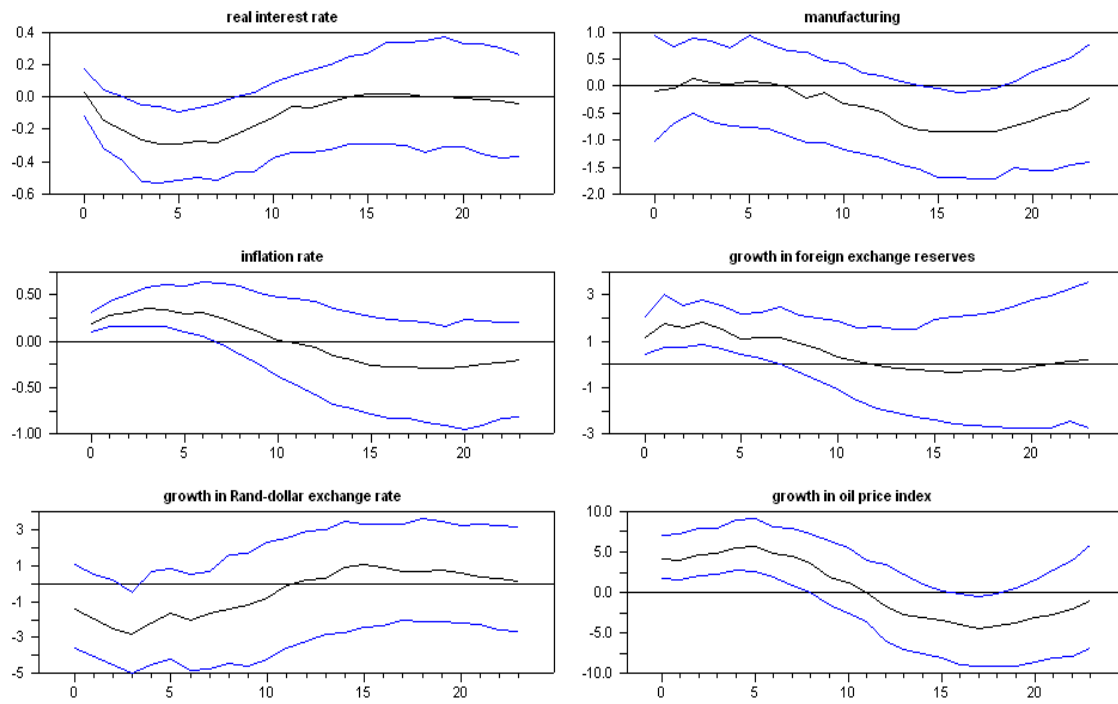


Responses to Inflation shock

Figure B3. Rand depreciation and inflation shocks



Responses to Rand depreciation shock

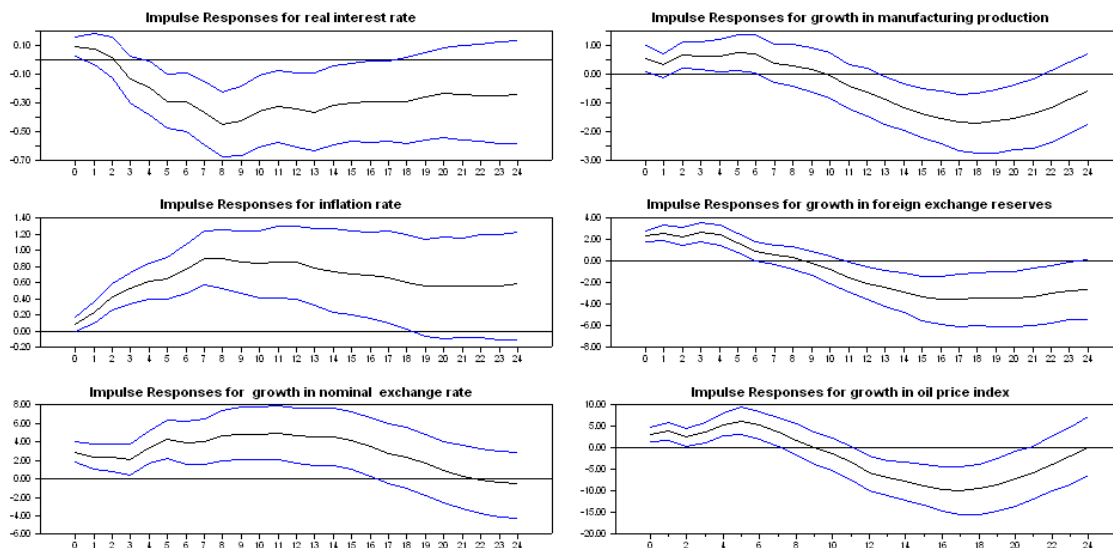


Responses to Inflation shock

Appendix C : Sensitivity results using penalty function

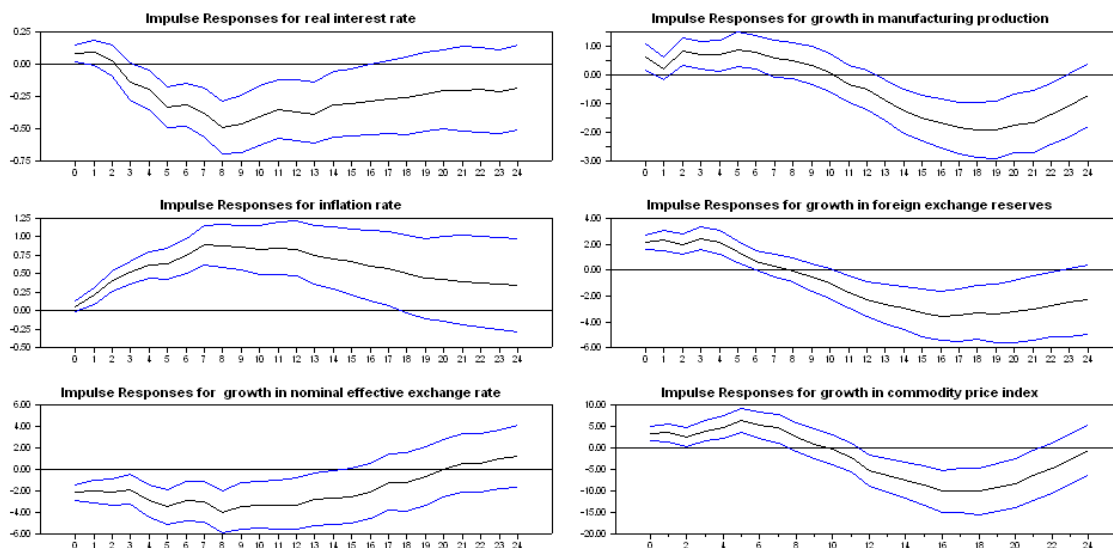
Figure C1: Exchange rate shocks (Penalty function)

Rand depreciation shock



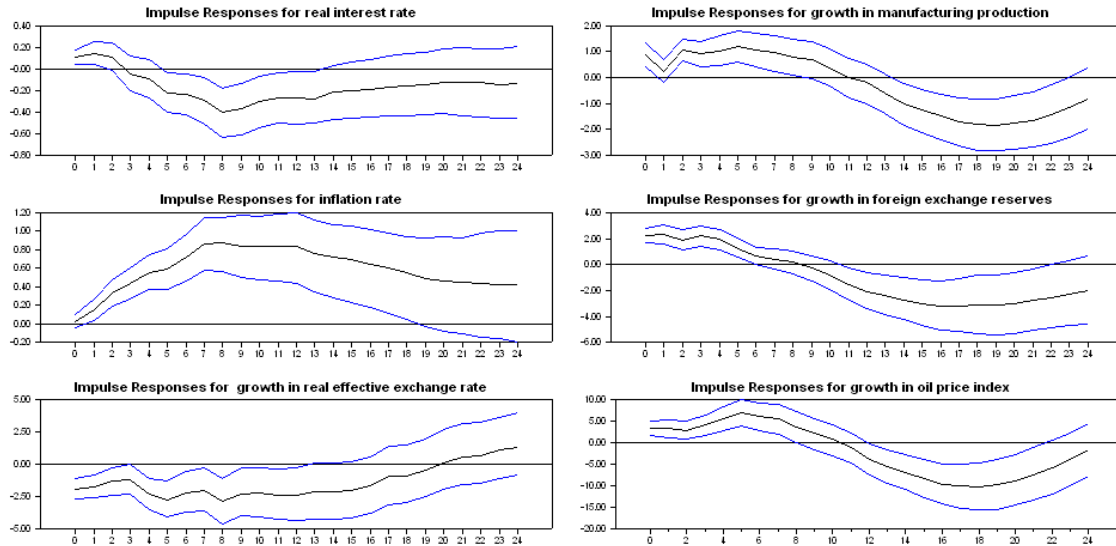
Impulse Responses with Penalty Function Approach

Nominal effective exchange rate depreciation shock



Impulse Responses with Penalty Function Approach

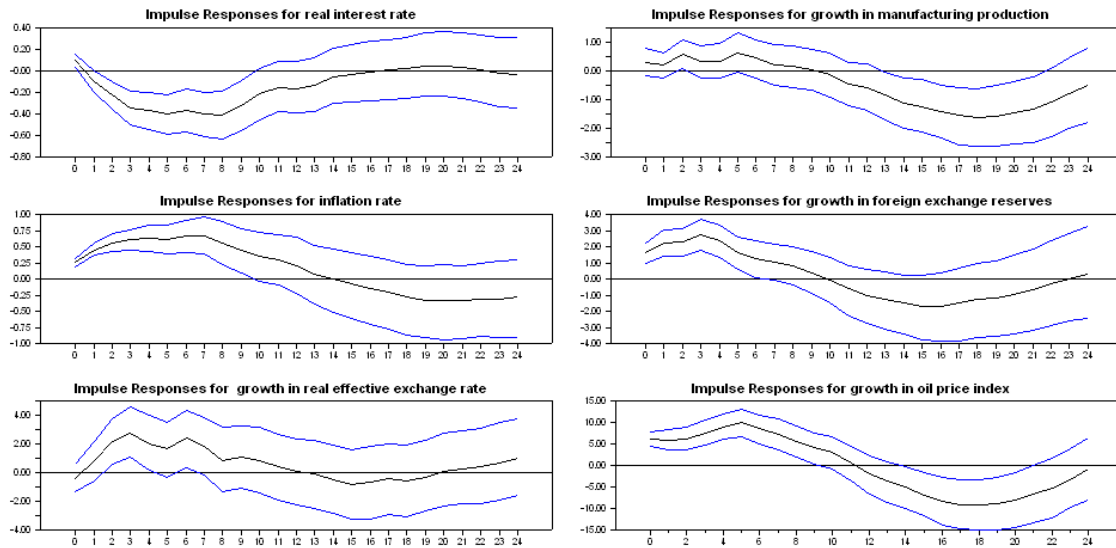
Real effective exchange rate depreciation shock



Impulse Responses with Penalty Function Approach

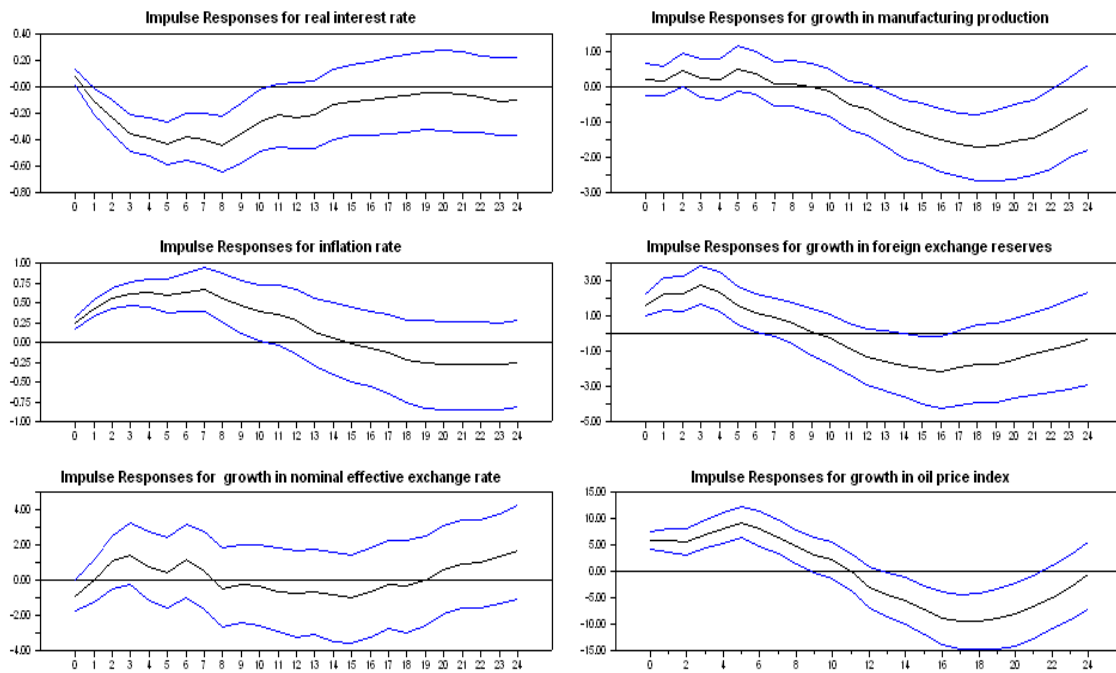
Figure C2. Inflation shocks (Penalty function)

Inflation shock



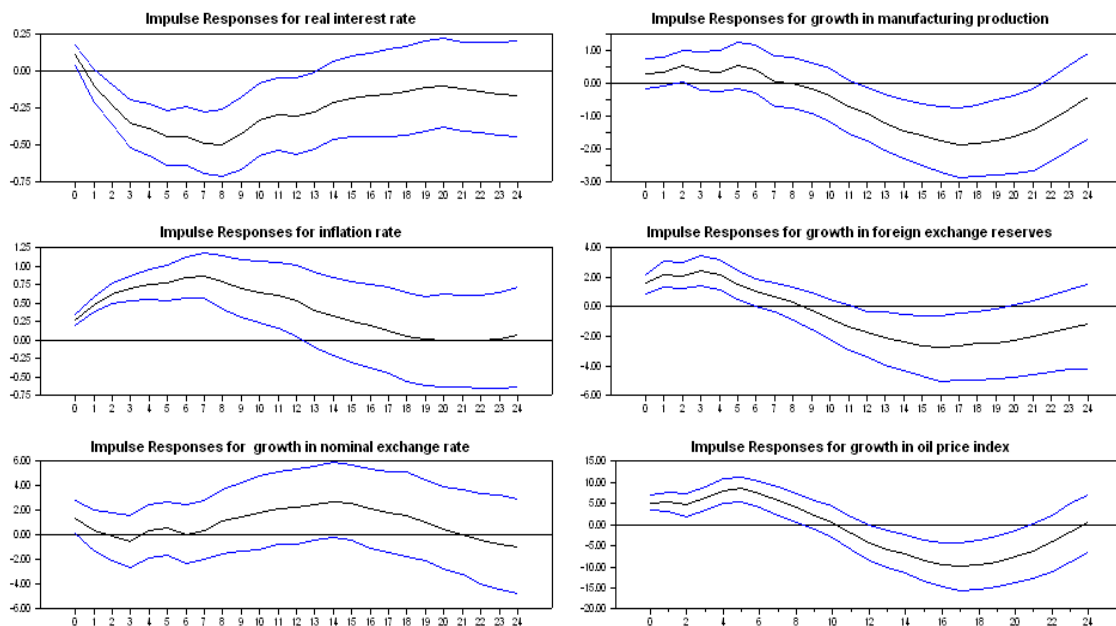
Impulse Responses with Penalty Function Approach

Inflation shock



Impulse Responses with Penalty Function Approach

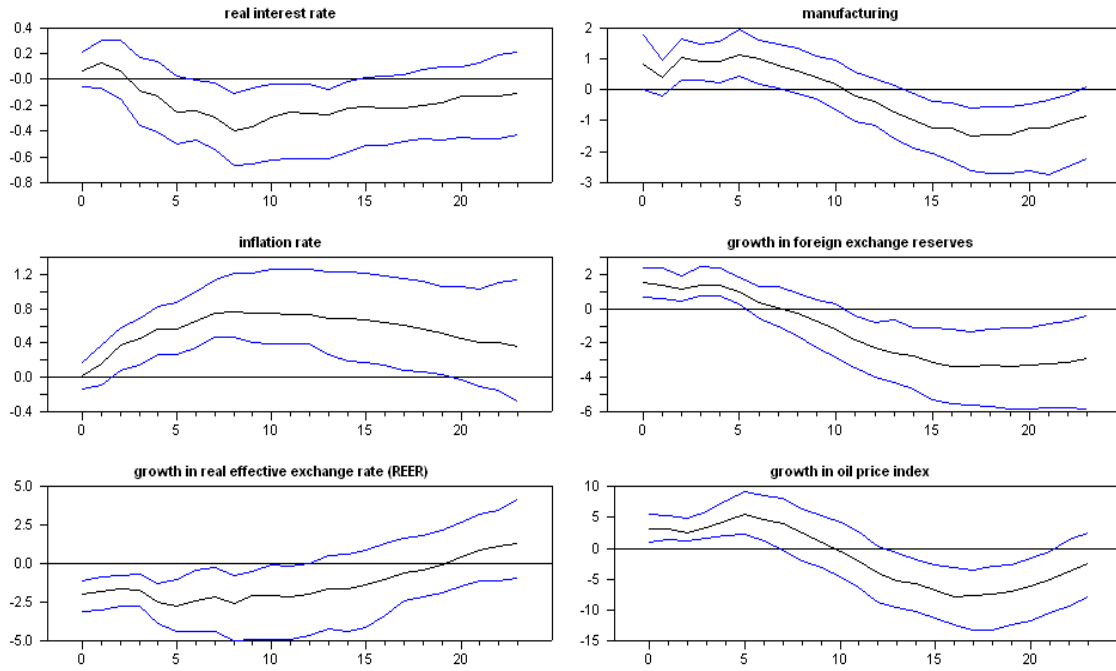
Inflation Shock



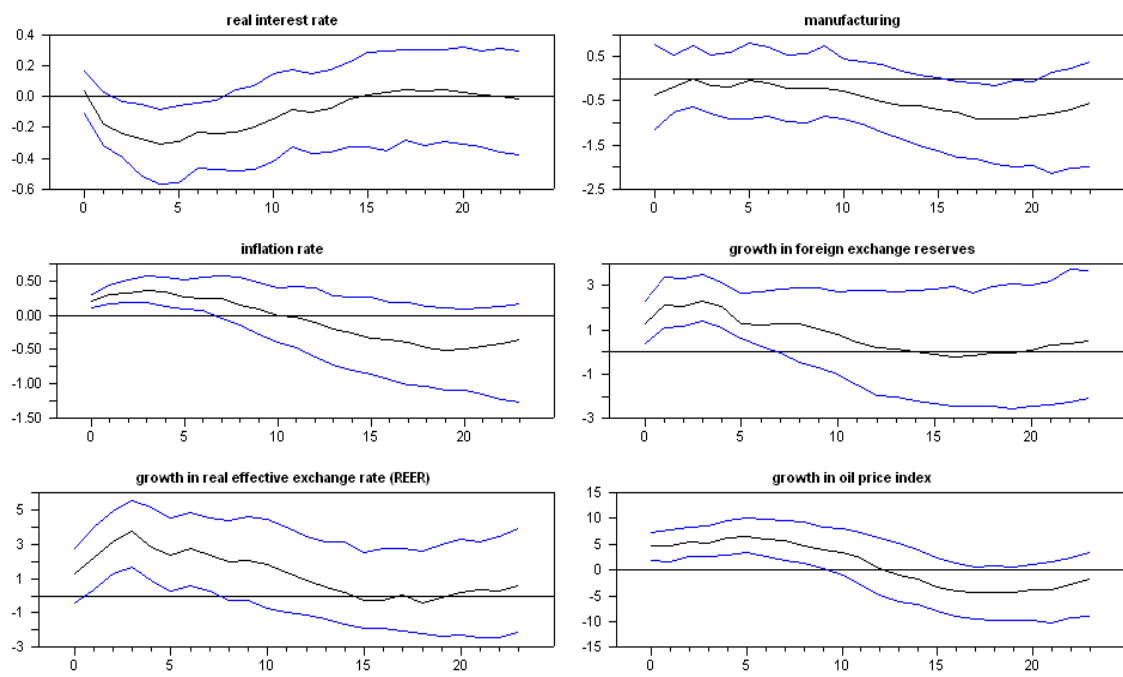
Impulse Responses with Penalty Function Approach

Appendix D. Orthogonality assumptions using foreign exchange definition

Figure D1. REER depreciation and inflation shock

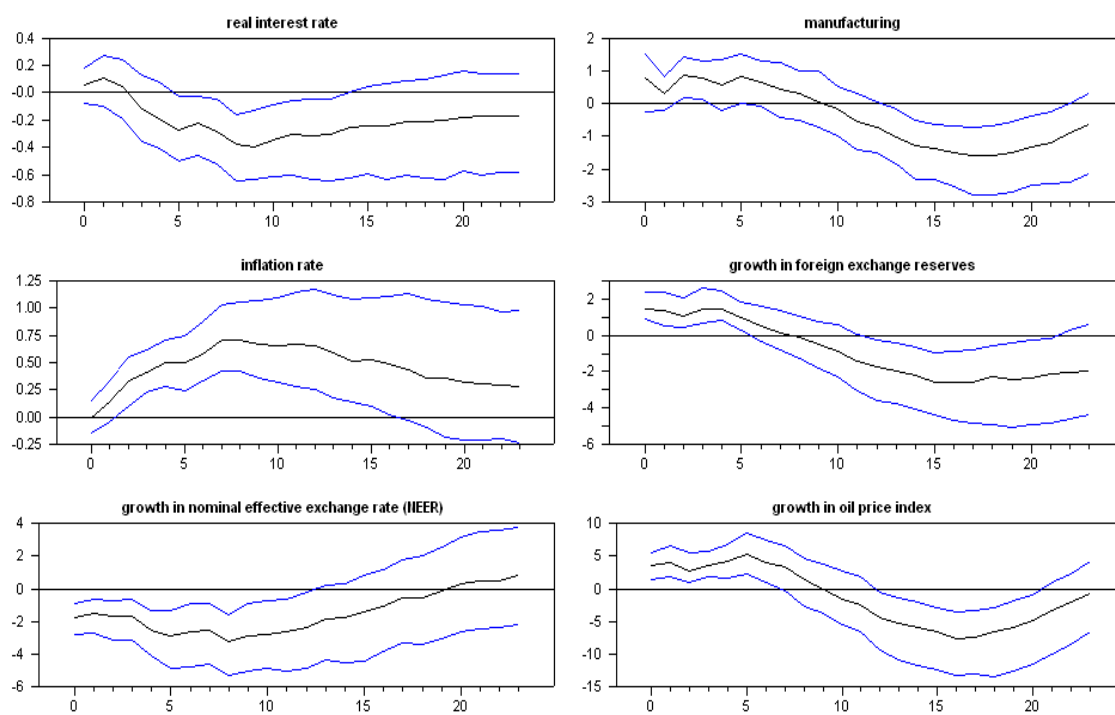


Responses to REER depreciation shock

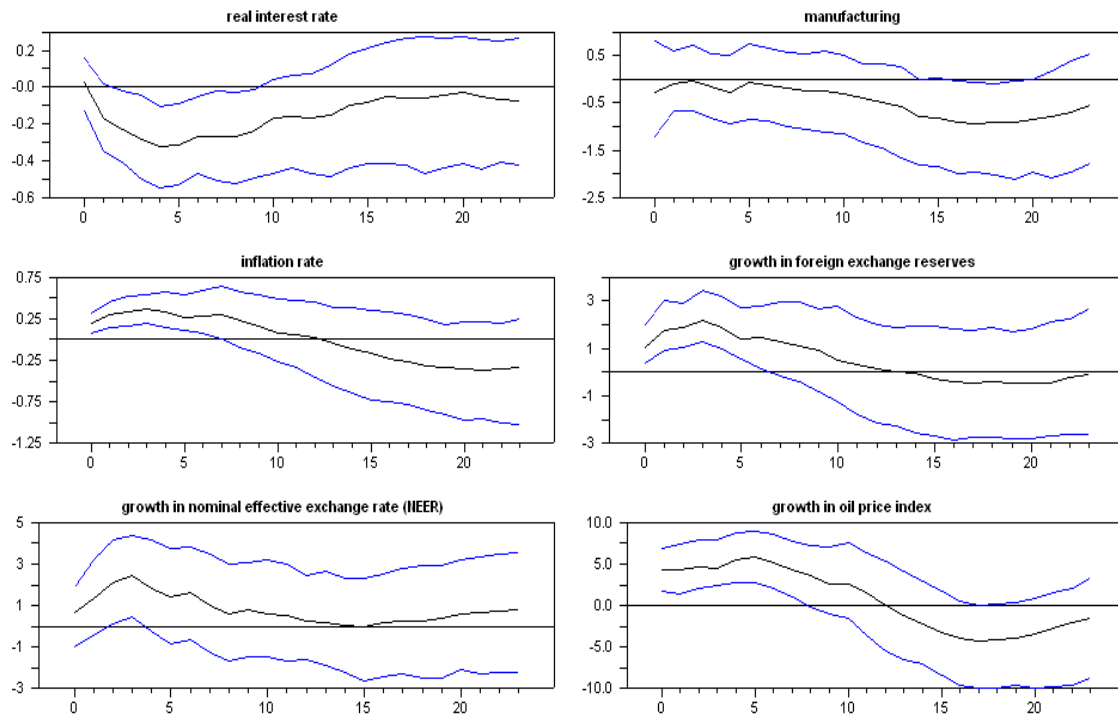


Responses to Inflation shock

Figure D2. Neer depreciation and inflation shocks

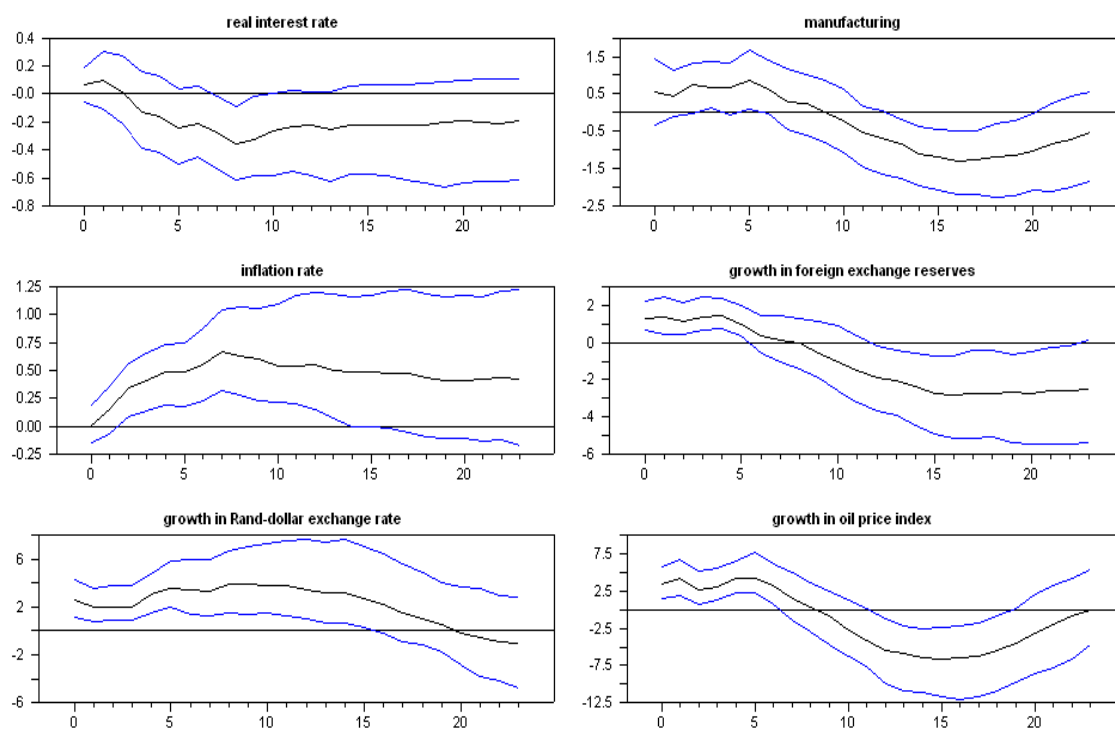


Responses to NEER depreciation shock

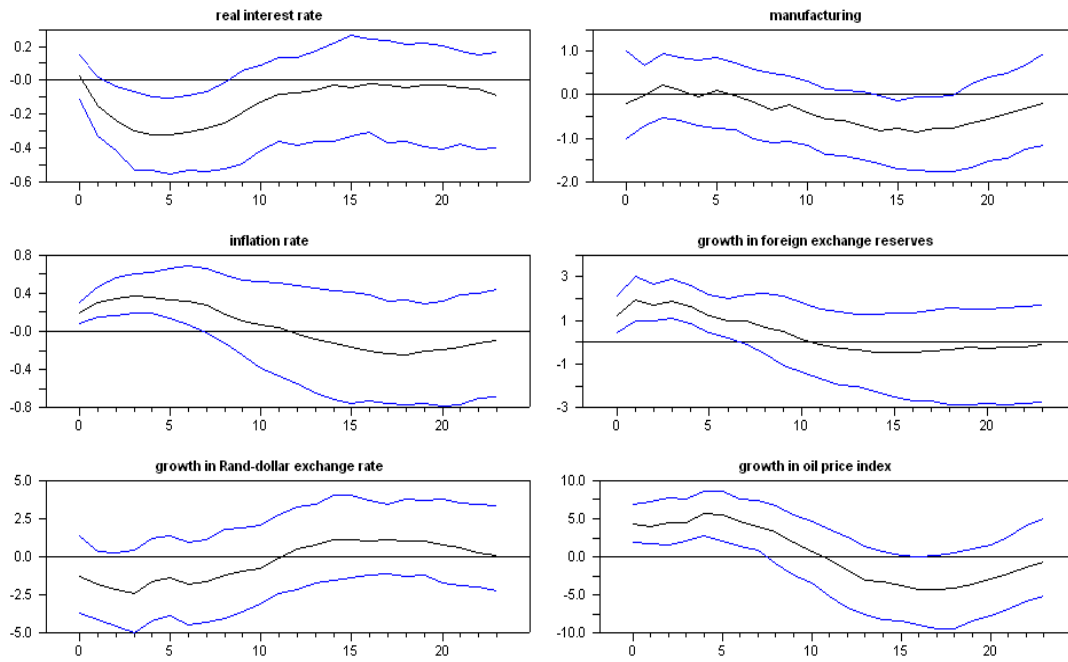


Responses to Inflation shock

Figure D3. Rand depreciation and inflation shocks



Responses to Rand depreciation shock



Responses to Inflation shock

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African Development Bank

Angle de l'avenue du Ghana et des rues Pierre
de Coubertin et Hédi Nour
BP 323 –1002 Tunis Belvédère (Tunisia)
Tel.: +216 71 333 511 – Fax: +216 71 351 933
E-mail: afdb@afdb.org – Internet: www.afdb.org